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Urban transport and climate change mitigation options to minimize Greenhouse Gas emissions and to promote sustainable use of public transport in Kigali, Rwanda

MASTER OF ENVIRONMENTAL SCIENCE

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Approval

This dissertation has been examined and approved as meeting the requirements for the award of the degree of Master of Science in Environmental Science.

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Statement of originality

This dissertation entitled "Urban transport and climate change mitigation policy options to minimize Greenhouse Gas emissions and to promote sustainable use of public transport in Kigali, Rwanda" is the original work of the author that has been accomplished at the University of Botswana along the period from August 2018 to October 2020. It has not been submitted to any other university for a degree or any other award.

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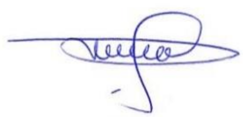

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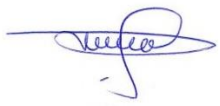

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Dedication

This dissertation is dedicated to Almighty God, my husband, my parents, my brothers and sisters, all relatives and friends who supported me in one way or another during my studies.

Abbreviations

AFOLU: Agriculture, Forest, and Land Use

BRT: Bus Rapid Transit

BIS: Bus Information System

CBG: Compressed Biogas

CoK: City of Kigali

CH_4: Methane

$C0_2$: Carbon Dioxide

CNG: Compressed Natural Gas

ITS: Information Transport System

GHG: Greenhouse Gas

GIS: Geographical Information System

IPCC: Intergovernmental Panel on Climate Change

MININFRA: Ministry of Infrastructure

NO_2: Nitrogen Dioxide

REMA: Rwanda Environmental Management Authority

RURA: Rwanda Utility Regulatory Authority

SO_2: Sulphur Dioxide

VKT: Vehicle Kilometer Travelled

UNFCCC: United Nations Framework Convention on Climate Change

USAID: The United States Agency for International Development

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Abstract

The study aimed at identifying urban transport and climate change mitigation options to minimize Greenhouse Gas emissions and to promote sustainable use of public transport in Kigali, Rwanda. Extreme climate events such as floods, drought, cyclones, and hurricanes to name a few are the indicators of climate change. Climate change is caused by the accumulation of greenhouse gases for a period of time. Worldwide, the transport sector emits an important share of greenhouse gases, especially transport in urban areas. In the period between 2006 and 2012 Rwanda recorded higher greenhouse gas removals compared to emissions due to AFOLU (agriculture, forest, and land use). However, in the period between 2013 and 2015 Rwanda recorded a rapid increase in greenhouse gas emissions due to economic growth and change in the way of life. The government of Rwanda adopted the fleet policy in July 2014 to reorganize public transport and reduce greenhouse gas emissions. Conversely, public transport still faced challenges such as rapid population growth, traffic increase with inadequate bus service, lack of bus priority lanes, traffic prioritization, and lack of real-time passenger information system. These challenges, to name a few, slowed down the use of public transport in Kigali city. However, according to Rwanda’s national communication to the United Nations Framework Convention on Climate Change (UNFCCC) by REMA emissions in the transport sector have been increasing tremendously for the past few years. The study used a mixed-method approach to generate both quantitative and qualitative data. Three different methods, namely, IPCC Tier 1 methodology (Intergovernmental Panel on Climate Change), documentary analysis, and key informants were used. IPCC inventory software was used to estimate GHG emissions. The fuel economy used in the software was estimated based on Vehicle Kilometer Travelled (VKT) and vehicle number. The results showed that the total greenhouse gas emissions from Kigali’s public transport were 45.26 Gg in $C0_2$ equivalent in 2012 and 2019 had doubled to 98.92 Gg in $C0_2$ equivalent. Also, the results showed that motorcycles were major contributors to GHG emissions under public transport followed by buses. Besides, the study identified climate change mitigation options and transport policy, such as fiscal policy, pricing policy, and dedicated bus lane. The findings of this study are anticipated to contribute to the development of next Rwanda's national communication under the UNFCCC. Additionally, the results will contribute to the implementation of Rwanda's Updated Nationally Determined Contribution (NDC) for climate change mitigation.

Keywords: Urban public transport; Transport policy; climate change mitigation; GHG emissions; Kigali.

Definition of Keywords

1. **TRANSPORT POLICY**: Transport policy involves the development of a set of concepts and proposals that are recognized to reach specific objectives relating to social, economic, and environmental circumstances and the functioning and performance of the transport system.

2.URBAN PUBLIC TRANSPORT: Urban public transport is transport that is made available to the urban general public. This type of transportation is characterized by passengers traveling in a group system and, it is accessible to all passengers, operated in a timely manner on a dedicated route. Urban public transport charges a displayed fee for each trip examples of public transport include city buses, trolleybuses, trams (or light rail) and passenger trains, rapid transit (metro/subway/underground) (Cross, 2016).

3. **SUSTAINABLE PUBLIC TRANSPORT**: Sustainable public transport is a type of transport that has a reasonable price, is well-organized and, can handle competition in a stable regional development. It helps in reducing emissions and waste to the acceptable rate that allows the planet earth to absorb them.

4. **GREENHOUSE GAS (GHG):** A greenhouse gas (GHG) is a gas that forms a blanket and limits radiant energy from escaping into the atmosphere and emits radiant energy within the thermal infrared range. Greenhouse gases cause the greenhouse effect. The main greenhouse gases are water vapor, carbon dioxide ($C0_2$), methane (CH_4), nitrous oxide (N_20), and ozone (0_3).

5. **CLIMATE CHANGE MITIGATION**: This is a way of reducing or preventing gas emissions that contribute to climate change. It can be achieved by shifting away from using fossil fuel, efficient use of energy, and by using renewable energy. Mitigation measures can also involve planting trees, and the trees are the sink for some greenhouse gases (Carbon sequestration).

CHAPTER 1: INTRODUCTION TO THE STUDY

Overview

This chapter presents the summary of urban transport emissions and their impacts and the significance of promoting sustainable urban public transport. It outlines the aims of the study, research objectives, and research questions. It also summarizes the research problem and gives content and geographical boundary description of the study area.

1.1 Introduction

Global climate change is a world's major challenge nowadays and greenhouse gases are accountable for climate change (Abraca sustainability, 2016). The fifth report of the Intergovernmental Panel on Climate Change (IPCC), stated that the growth of greenhouse gas emission will raise the global temperature by 4.8% (Intergovernmental Panel on Climate Change, 2007). The first greenhouse gases include carbon dioxide ($C0_2$), water vapor (H_20), methane (CH_4), and nitrous oxide (N_20); and the main source of $C0_2$ was from urban areas through the on-road vehicle emissions (Kakouei, Idris, & Vatani, 2012). Greenhouse gas emissions have increased rapidly nowadays due to the increased economic activities and the use of fossil fuels (Ramachandra & Shwetmala, 2009). The transport sector is the main emitter of greenhouse gases worldwide and, the population's choice of mode of transport determines the level of impacts to the environmental sustainability, and ultimately ecological quality (Collins & Fynn, 2007).

In the energy sector, transport ranks second after the industry sector contributor to global carbon dioxide emissions from fossil fuel combustion (Jiemian, Hongyuan, & Mohanty, 2005). A study by Kahn-Ribeiro (2007) indicated that the transportation sector had 23% of greenhouse gas emissions worldwide, however, the emissions increased by up to 25% in developed countries (Kahn-Ribeiro, 2007). Also, it was noted that the growth of urban areas influences the development of road infrastructure and it makes urban areas most vulnerable to climate change (Chomitz, 1996). Addressing climate change in the transport sector requires an understanding of the relationship between transportation and the spread of urban settlements.

Over the 20 years, Rwanda experienced rapid economic growth and development which led to the growth of urban mobility and fuel use (Rwanda Environment Management Authority, 2018a). In the 2012 census, the annual population growth rate was at 4.1%, which increased from 4.6% in 1978 to 16.5% in 2012 (see Figure 1.1) and this growth was estimated to keep rising by up to 35% in 2020 (Rwanda Ministry of Infrastructure, 2015).

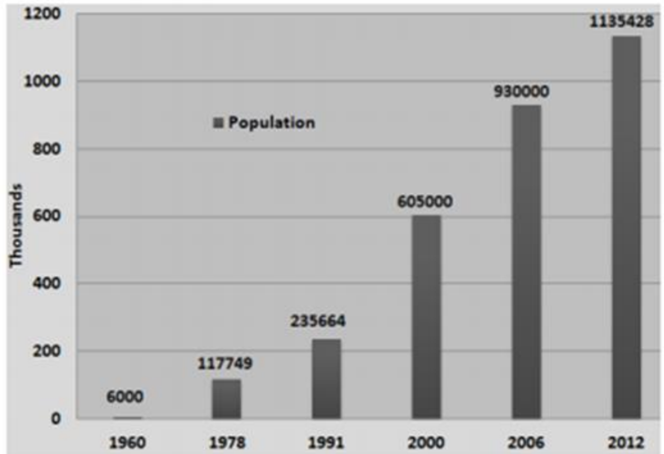

Figure 1.1 Demographics dynamics of Kigali city

Source: REMA (2013)

The rapid growth of the urban population in Kigali caused the increase in the use of public and private vehicles, the year 2012 to 2017 showed a 40% increase in vehicles and a 44% increase in fuel consumption (258.291.000 liters in 2012 and 461.880.000 liters in 2017) (MININFRA, 2018).

The use of electronic payments (Card payments) increased the number of passengers in public transport from two hundred and fifty thousand in 2013 to four hundred and fifty thousand in 2016; hence almost 40% of the Kigali population in 2016 depended on the use of public vehicles (Tumwembaze, 2017). Additionally, the motorcycle taxi sector in Rwanda as a whole, and certainly in Kigali, is growing actively. Nationally, the number of authorized moto-taxis increased by 280% between 2009 and 2011, while the number of vehicles used in public transport overall increased by 233% (RURA, 2011).

In Rwanda, GHG removals dominated over emissions for the period between 2006 and 2012 due to AFOLU (agriculture, forest, and land use) (REMA, 2018a). However, due to economic growth, the change in lifestyles, and increased motorization, Rwanda recorded a rapid increase in GHG emissions during the period between 2013 and 2015 (REMA, 2018b). The analysis of the gas contribution to the total GHG emissions showed that CO_2, CH_4, and CHF were the dominant contributors to the total GHG emissions respectively (REMA, 2018b).

1.2 Research problem statement

The generation of greenhouse gas (GHG) emissions through human activities is among the major causes of environmental degradation and climate change (United States Environmental Protection, 2017). A study by Collins and Fynn (2007) showed that 82% of GHG emissions were carbon dioxide (CO_2). Additionally, a significant portion of GHG emissions is created through transportation (United States environmental protection, 2017). Also, the choice of transportation mode determines the level of impacts of environmental sustainability, and eventually environmental quality (Collins & Fynn, 2007).

Transport is the second largest sector after the energy sector, contributing to global carbon dioxide emissions from fossil fuel combustion (Jiemian, Hongyuan, & Mohanty, 2005). In 2005 transport accounted for 23 percent of global CO_2 emissions and road transport accounted for 73 percent, this was followed by international shipping and international aviation (Jiemian, Hongyuan, & Mohanty, 2005). According to a UNFCCC report (2011), greenhouse gas emissions from industries, transport, and other sources are a major challenge in developing cities including Kigali, the capital city of Rwanda. However, developing countries have not put in place initiatives for reducing emissions from the transport sector, despite the fact transport is the sector where emissions have increased the most by 14 percent from 1990-2008 (United Nations Framework Convention on Climate Change, 2011). In a business as usual scenario, emissions from the transport sector are expected to grow by 25.8 percent by 2020 compared to 1990 levels (United Nation Framework Convention on Climate Change, 2011).

Economic development, growth in fuel consumption, and GDP (Gross Domestic Product) are the major cause of increased greenhouse gas emissions in Kigali and, on-road transport uses 80% of imported fuel (REMA, 2018). A study by Cederborg & Snöbohm (2016) indicated that there is a positive correlation which suggests that per capita GDP growth leads to increasing per capita carbon dioxide emissions. Additionally, the increase in greenhouse gas emissions is related to limited space and inadequate infrastructure, which results in increased urban road traffic congestion, lost time, wasted resources, CO_2 emissions, and adverse health impacts (Mbonyinshuti, 2018). The fleet policy of the Government of Rwanda in July 2014 was adopted to reorganize public transport, as a way of reducing GHG emissions, by finding solutions to the problems that have been affecting public transport (MININFRA, 2014). There was a problem with professionalism, which caused disorganized public transport and poor service delivery, and it resulted in a decreased number of people using public transport. The policy aimed at promoting timely services cost-effectively and ensure safety and security for passengers. However, public transport still faces challenges of rapid population growth and traffic increase with inadequate bus service such as overloading, congestion at the bus stations (especially during peak hours), and poor planning, among others, that have ensured poor service delivery.

Additionally, the lack of bus priority of dedicated bus lanes to give public transport priority, traffic prioritization, and lack of real-time passenger information system, to name a few, has slowed down the use of public transport in Kigali city (Bajpai, 2014). The energy sector had an increase of greenhouse gas emissions by 4.2% between the year 2006 and 2015 hence, it was still a major contributor to GHG emissions in Kigali followed by the waste sector (REMA, 2018b). The increase in greenhouse gas emissions in Rwanda was associated with the increased average temperature by 0.79^0C between the year 2012 and 2014 and, Kigali had the highest average temperature which rose from 16^0C to 21^0C (USAID, 2018). However, In 2018 Rwanda had an average temperature of 28^0C and it was assumed to keep increasing in a business as usual scenario (USAID, 2018). It is expected that improved regulations might deliver improvement in Kigali public transport and can contribute to the GHG emissions reduction and will ultimately provide to the decline of the rising global temperature. Therefore, there is a need to identify effective transport and climate change mitigation options towards reducing GHG emissions and promoting the sustainable use of public transportation in Kigali.

1.3 Aim/purpose of the study

The study aims to identify urban transport and climate change mitigation options to minimize Greenhouse Gas emissions and promote sustainable use of urban public transport in Kigali, Rwanda.

Table 1.1 Summary table of research objectives and questions

Research objectives	Research questions
1. To estimate GHG emissions of urban public transport in Kigali from 2012 to 2019	1.1 What is the estimated quantity of GHG emissions from public transport in Kigali? 1.2 Which public transport modes contribute more to the GHG emissions in Kigali?
2. To identify GHG emissions reduction options for urban public transport in Kigali	2.1 What are the climate change mitigation measures for public transport? 2.2 Which political, environmental, and economic instruments could assist in emissions reduction in public transport in Kigali?
3. To determine transport policy options for urban public transport in Kigali	3.1 Which transport policy measures can be adopted for urban public transport to minimize GHG emissions? 3.2 To what extent have formulated transport policies for urban public transport been implemented in Kigali?
4. To explore strategies for promoting the use of urban public transport in Kigali	4.1 How have recent innovative initiatives and best practices for promoting the use of public transport been implemented? 4.2 What are the barriers and limitations to promoting the use of urban public transport in Kigali?

1.4 Scope of the study

1.4.1 Conceptual scope

The study focused on estimating greenhouse gas emissions from Kigali public transport and proposed transport policy and climate change mitigation options. Kigali public transport has buses, motorcycles, and taxicabs as vehicle categories. Additionally, the trips that take place entirely in Kigali city were analyzed to estimate the urban public transport activities. Compared to other cities in Rwanda, Kigali has more public transport means, and about 40% of the Kigali city population uses public transport (Tumwembaze, 2017). According to the yearly report book of the National Institute of Statistics of Rwanda (2018), the total number of registered vehicles in Rwanda was 216204 vehicles. The percentages of Kigali public transport from the total number of registered vehicles for taxicabs, motorcycles, and buses were 0.4%, 7.1%, 0.2% consecutively (National Institute of Statistics of Rwanda, 2018). The city of Kigali had three districts namely: Nyarugenge, Kicukiro, and Gasabo, and each district had one buses Company, one taxicab union, and one motorcycle union. Each union is made by different cooperatives depending on the number of taxicabs or motorcycles in that district.

Buses in Kigali city operated in three specified network routes (in the three districts) with their stops. Taxicabs and motorcycles also accessed those routes, but they also accessed other minor roads in Kigali city to feed buses. The study included different vehicle characteristics, such as engine type, engine capacity, and vehicle age. Also, the study considered kilometers traveled or the number of trips and fuel consumption. The study excluded private vehicles, trucks, and intercity public transport, and all external traffic because the study only focused on urban public transport vehicles in Kigali city.

1.4.2 Geographical scope

The capital, Kigali, is located near the center of Rwanda and its geographical location is about 10 57' south and longitude 300 04' EST (Central Intelligence Agency, 2012). The study was carried out in Kigali city as it has been Rwanda's economic and cultural hub, and it has the majority of transport means compared to other cities in Rwanda. Furthermore, almost 35% of the Rwanda population lived in urban areas, and Kigali provides accommodations for about half of the urban population (Republic of Rwanda, 2015). In 2016 Kigali had around 1,200,000 inhabitants (City of Kigali, 2016) 40 % of the Kigali population public transport (Tumwembaze, 2017). In 2006, Kigali had almost 1000 public vehicles, and it was assumed to keep increasing (City of Kigali, 2016).

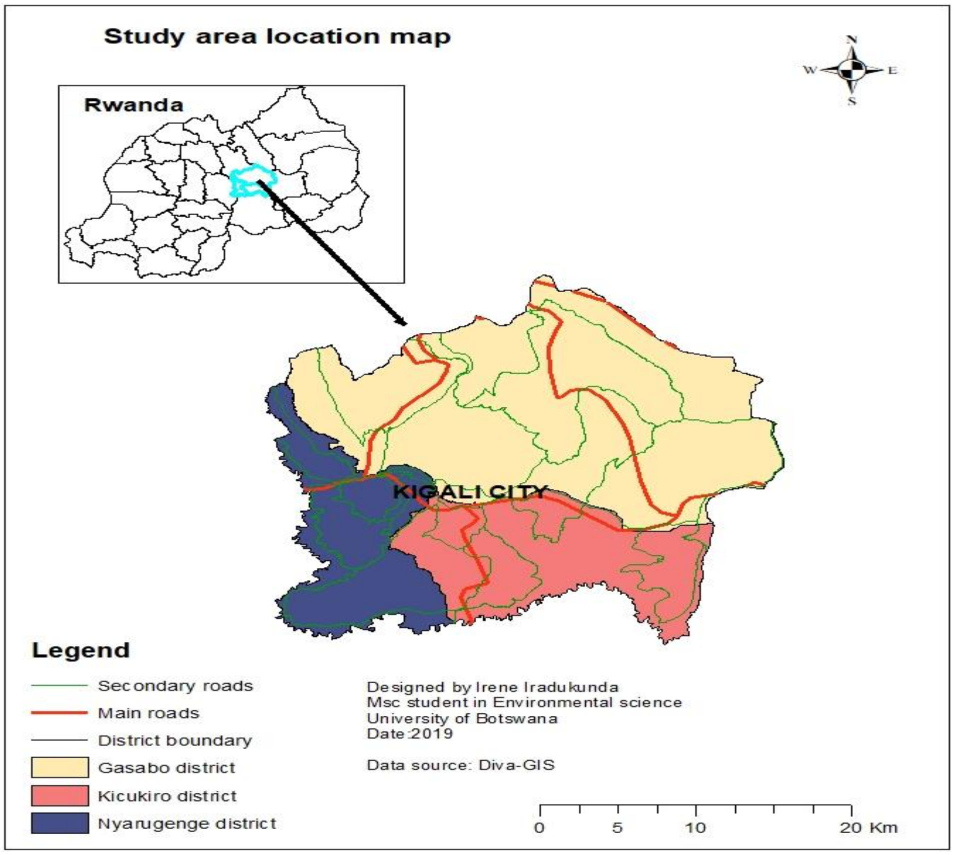

Figure1.1 Location Map

Source: Author's field data (2019)

1.5 Significance of the study

The study will inform researchers of the estimated greenhouse gas emissions from Kigali public transport. The study results will inform the policy-makers and regulatory bodies to implement environmentally sound policies and regulations of climate change mitigation in the transport sector. Also, this study will contribute to the implementation of Rwanda's Updated Nationally Determined Contribution (NDC) for climate change mitigation. Rwanda's unconditional and conditional contribution is 38% reduction in GHG emissions under a business as usual scenario by 2030, equivalent to an estimated mitigation level of up to 4.6 million tCO_2 equivalents (Republic of Rwanda, 2020).

The study will provide recommendations to public transport stakeholders with the hope to change their behavior and reduce greenhouse gas emission activities. It will also provide data about the development of next Rwanda's national communication in the transport sector for the United Nations Framework Convention on Climate Change (UNFCCC) (Ministry of Natural Resources, 2012). The final report will provide a source for secondary data that would be used by future researchers in their investigations to fulfill the remaining gaps.

Furthermore, the study will facilitate the implementation plan of new urban agenda habitat III by indicating the potential of sustainable urban development through public transport. Also, this study will share knowledge on the implementation of Sustainable Development Goal 11 (Sustainable cities and communities) and Goal 13 (Climate action) (United Nations, 2017). The study will again be a guide for implementing Agenda 21, a program action for sustainable development goals such as improving the social, economic, and environmental quality of human settlements. This goal's main objectives include promoting sustainable energy and transport systems in human settlements (United Nations Conference on Environment and Development, 1992).

1.6 Description of the study area

1.6.1 Climate

Rwanda enjoys a tropical climate moderated by hilly topography. The country experiences four climatic seasons, namely: Long rainy season (March-April-May); short rainy season (September-October-November); long dry season (June-July-August), and short dry season (Mid December-January-February) (Rwanda Environmental Management Authority, 2018c). Besides, Rwanda's average temperature of 20^0C varies with topography across the country. Besides, Kigali experiences a tropical wet and dry/ savanna climate. However, the annual weather report of 2018 presented an average of the high temperature of 28^0C and an average of the low temperature was 16^0C, precipitation 41.2 mm, and the humidity 57% Dew Point: 13 °C (Safari, 2012). Furthermore, Rwanda's climate variability projection shows an expected decline in mean rainfall and the number of rainy days for the period of 2017 to 2050, mainly in the south and central Kigali provinces of Rwanda (Rwanda Environmental Management Authority, 2018c). Figure 1.3 below shows the annual variations of temperatures at Kigali stations for 1971-2016.

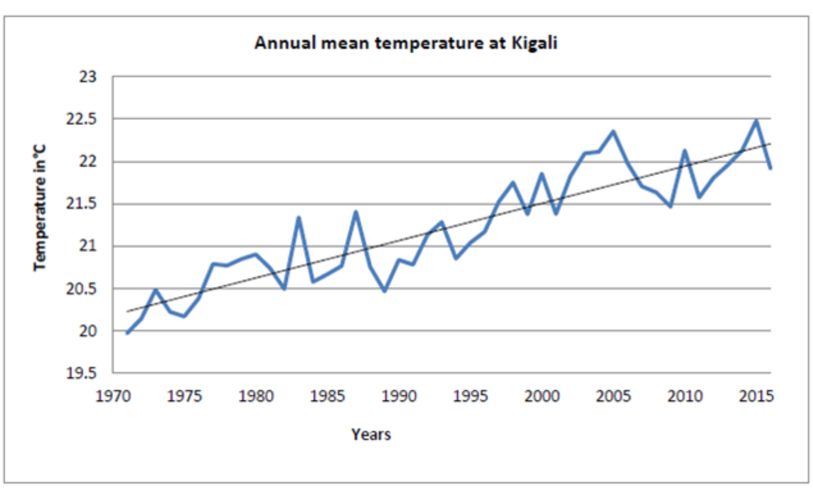

Figure 1.2 Annual variations of temperatures at Kigali stations 1971-2016

Source: REMA (2018)

1.6.2 Population

The fourth Rwanda population census of 2012 indicated that the total population increased with the rate of 29% from 8,128,553 people in 2002 to 10,515,973 people in 2012. However, the statistical yearbook of 2017 estimated that the population projection is 11,262,564 in 2015 (Rwanda Environmental Management

Authority, 2018c). In 2012 Rwanda presented the highest population density of 416 people per square kilometer. This population density had a growth rate of 2.8% per year and it is amongst the highest in Africa (Safari, 2012). There has been an increase in population growth rate to 3.1% from 1978 to 1991 and it fell to 1.2% from 1991 to 2002 due to the genocide of Tutsi (Safari, 2012).

In 2012, Rwanda had an annual urban growth of 4.5%, exceeding the worldwide average of 1.8%, and it was among the least urbanized countries in the world with 16, 5%, (NISR, 2012). The report from MININFRA in 2015 showed that Kigali was the primary urban center hosting around 48% of urban residents and integrating most migrations due to the concentration of economic activities (Ministry of Infrastructure, 2015). The internal migration between provinces from rural to urban areas causes the rapid growth of the urban population.

Fourteen percent (14%) of the Rwandan population has access to electricity, though this is concentrated in the capital city, Kigali (Ministry of Infrastructure, 2015). However, in rural areas, limited access to power is universal. This limited access to electricity pushes rural populations to depend on wood, agricultural residues, charcoal pits, and organic gas as significant sources of energy.

1.6.3 Economy

Future Rwanda's socio-economic development was imprecise in 2012, due to population growth and climate change pressure on land, water, food, and energy resources (Safari, 2012). However, the country's overall economy is growing at a significant rate, and it has been outstanding over the past few decades (Malunda & Musana, 2012). This economic growth is traced back to the government’s commitment to achieving sustainable economic growth and creating employment opportunities for its people. The commitment has enabled the country to quickly rehabilitate and stabilize well after the 1994 tragedy (Tutsi genocide) (Malunda & Musana, 2012). Rwanda's economic growth depends mostly on the agriculture sector which remains unharmed regardless of the emergence of other drivers such as the service sector. The industry occupies 75% of the labor force, contributing to one-third of the country's GDP, and generates more than 45% of the country's export revenues (World Bank, 2011).

According to Malunda & Musana (2012), the service sector contributed to almost 39% of the country's GDP and 6.5% of the working population. This sector is subdivided into two categories trade and transport. Rwanda committed to becoming a service-based hub to serve the east Africa region to disrupt its landlocked environment. The commitment enabled Rwanda to become a second service hub after Mauritius in 2013-2014in sub-Saharan Africa (Malunda & Musana, 2012). This commitment boosted service sector growth with an increase of a significant share of foreign private investments.

According to Malunda and Musana (2012), Rwanda faced challenges in integrating well into the east African regional and global markets. This slow integration was caused by its landlocked nature and a small domestic market. Additionally, limited buying power and insufficient infrastructure contributed to Rwanda's slow integration into regional and global markets.

1.6.4 Spectrum of the transport sector in Rwanda

A report by the Rwanda Utility Regulation Authority (2018) showed that transport infrastructure in Rwanda was consisted of: (a) Road transport – It is the main transport infrastructure used for passengers and goods transportations. It is developed with a road network and consistent to a road density of 0.53 km/sq km; (b) Air transport –It is comprised of one airport and six aerodromes spread across the country, and (c) water transport - limited mainly to Lake Kivu (Rwanda Utility Regulation Authority, 2018).

Compared to other countries in East Africa, Rwanda has the highest costs of the value of imports and export of 40%, 12% in Kenya, and 36% in Uganda and, it lacks a rail transportation system (World Bank, 2017). Also, Rwanda has a 300,000 Km well-established road network of classified and unclassified roads (Classified roads are the roads that are intended to feed and, connect different areas) (World Bank, 2017). In addition, These classified roads have 14,400 km which is divided into 2,749 km of National Roads and, 3,848 km and 7,800 km of District Class 1 and 2 Roads, respectively (World Bank, 2017). However, only 1,250 km of national and 58 km of district roads are paved. Furthermore, Rwanda achieved remarkable progress in improving and implementing intensive road rehabilitation national road networks over the last decade. Table 1.2 shows the trends of the number of licensed vehicles in public transport from 2015 to 2019.

Table 1.2 Trends of fleets for licensed transport

Category of licensee	Q2 2015	Q2 2016	Q2 2017	Q2 2018	Q2 2019
Public bus and minibus companies and cooperatives	3,924	3,970	4,011	3493	2,948
Motorcycles cooperatives	31,002	31,149	31,296	33892	21,578
Car rental companies	440	453	483	596	731
Taxi cab companies and cooperatives	1,195	1,244	1,285	1189	1,052

Source: (RURA, 2020)

The government of Rwanda has put in place several initiatives in Kigali city to enhance public transport such as electronic ticketing systems for intercity buses, mobile phone-based booking systems in some intercity bus companies, Wi-Fi internet, and automated fare collection were introduced in buses in Kigali city (Rwanda Utility Regulation Authority, 2018). Also, booking systems and driver management systems were developed for motorcycles and taxicabs; to mention a few technologies developed for Kigali public transport. According to the Rwanda utility Regulation Authority report (2018), these innovations have increased the number of passengers using public transport (RURA, 2018). Public transport passengers increased from two hundred and fifty thousand passengers in 2013 to four hundred and fifty thousand passengers in 2016, this implies that about 40% of the Kigali city population was using public transport (Tumwembaze, 2017).

1.6.5 Energy

In 2012, Rwanda's energy consumption represented 86% which was divided into biomass (firewood, agricultural residues) and petroleum products (e.g. gasoline for vehicles, fuel for airplanes, diesel, kerosene, fuel oil, and liquefied petroleum) (Ministry of Natural Resources, 2012). It was noted that wood and charcoal energy was used by more than 90% of the population (Safari, 2012). Besides petroleum products had 11%, electricity had 3 % (56% of hydropower and 56% of thermal energy) of total energy consumption (Ministry of Natural Resources, 2012).

In the year 2005 energy sector had the highest emissions of 380,000 tons of CO_2 emission and the industrial process represented 151,000 tons of CO_2 emissions (Ministry of Natural Resources, 2012). Rwanda initiated several measures to implement Intended Nationally Determined Contribution (INDC) for climate change mitigation under the transport sector such as: promoting the use of public transport, improving transport infrastructure, and introducing vehicle emissions standards and regulations, and integrating national transportation planning (Munyazikwiye, 2017).

1.7 Conclusion and summary

This chapter detailed the research problem statement, it elaborated on the study's aim, which is to identify urban transport and climate change mitigation options to minimize GHG emissions and to promote sustainable use of public transport in Kigali, Rwanda. Also, this chapter developed the research objectives and research questions. The primary purpose of the study is to identify the transport and climate change mitigation policy options to minimize Greenhouse Gas emissions and to promote the use of sustainable urban public transport in Kigali; which is detailed in the next chapter. Furthermore, the chapter describes the study area; climate, population, economy, energy, and transport spectrum.

The next chapter shall discuss the urban transport emissions and climate change mitigation options. Also, the chapter shall identify the research gap and focus on the sustainable use of public transport. In addition, various aspects that are critical in understanding the concepts for the need to reduce emissions in urban public transport in the Kigali context were described in the chapter. Furthermore, the chapter elaborates on the conceptual framework that the study will apply.

CHAPTER 2: LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

Overview

Chapter one elaborated on the aim of the study, research objectives, and research questions. It also described the study area focusing on climate, population characteristics, energy, and transport spectrum. Chapter 2 will discuss several studies on emission reduction options and transport policy options for urban public transport in various developing countries such as Costa Rica, India, etc... Despite the findings presented to different governments, some countries such as India still have challenges in implementing policy and mitigation options for sustainable use of urban public transport.

In addition, chapter 2 provides a discussion on various aspects that is critical in understanding the concepts for the need for emission reduction in urban public transport in the Kigali context. The Chapter also discusses emission reduction dimensions and their influencing factors intending to identify the critical knowledge gap. Furthermore, the chapter highlights the conceptual framework. The conceptual framework is developed to assess and monitor the progress towards the sustainability of an urban built environment.

2.1 Literature review

2.1.1 GHG emissions reduction options for public transport in developing countries

This section focused on the following subtopics: the overview of public transport emissions in developing countries; emission reduction options; climate change mitigation options, and barriers and limitations to reducing transport GHG emissions in developing countries**.**

Overview of public transport emissions in developing countries

Asia is a fast-growing region, and its economic growth has been steady over the past two decades. Transport plays a crucial role in economic growth and social development, hence a reduction in transport activities towards emissions reduction has not been an option in Asia (Leather, 2009). The bottom-up approach, a method that has been used in most Asian countries to estimate vehicle emissions; involved measuring fuel consumption and distance for each kind of vehicle-fuel combination. Additionally, most Asian countries adopted an approach that helped in reducing emissions-intensive car-based development patterns to less carbon-intensive transport modes, and improve the fuel efficiency of vehicles (Leather, 2009).

A study by Ramachandra & Shwetmala (2009) in India focused on designing and implementing appropriate technologies and policies in place of mitigation measures for the on-road transport sector. The study showed that there was an increase in the number of vehicles by 92.6% from 1980 to 2004, caused by the government's globalization and liberalization policies in the 1990s (Ramachandra & Shwetmala, 2009). These vehicles mostly consumed fossil fuels and, these fuels are significant contributors to greenhouse gases through emitting particularly $C0_2$ (Ramachandra & Shwetmala, 2009). The study concluded that the transport sector in India emitted an estimated amount of 258.10 tons of CO_2, of which 94.5% was from road transport (Ramachandra & Shwetmala, 2009). In addition, the study prepared a decentralized emission inventory to design and implement appropriate technologies and policies in place of mitigation measures for the road transport sector. The study focused on road transport, rail, and ship emissions in general in different states of India. The estimated emissions focused on different gases such as CO_2, CH_4, CO, NO_x, N_2O, SO_2, PM, and it used the IPCC Top-down approach for data collection. A Top-down approach has the advantage of leveraging existing data and rapid installation results, however, the approach omits emission source data and has a scope uncertainty (Alcorn & Lloyd, 2009). In addition, the study does not focus on urban public transport emissions in particular. This study will focus on urban public transport emission and will use an IPCC bottom-up approach, it gives a well-defined boundary and has a higher resolution and detailed data (Alcorn & Lloyd, 2009).

Air pollution is on the rise in Sub-Saharan Africa due to the usage of fossil fuel and usage in a high percentage of old vehicles imported from developing countries (Agarana, Bishop, & Agboola, 2017). This importation of old cars poorly maintained roads increases exhaust emissions, which affect air quality. On this note, air pollution caused by an increase in motorization is responsible for about 49,000 deaths per year in the region (Agarana, Bishop, & Agboola, 2017).

A simple computer software method was used to analyze the reduction of carbon dioxide from transportation projects, which is on the rise in sub-Saharan Africa cities. For instance, Lagos, a Nigerian city demonstrated this unusual situation with a linear programming system (Agarana, Bishop, & Agboola, 2017). The study concluded that Nigeria should pay more considerable attention to using high-quality fuel for transportation and the government of Nigeria should construct the right roads. Specifically, the amount of money needed to achieve a high quality of fuel, and the construction of the right roads should not be compromised. The study gave a thoughtful approach to using high-quality fuel and, it could help developing countries for mitigating GHG emissions in the transport sector.

Emission reduction options

The transport sector is an important and rising contributor to GHG emissions, hence emission reduction options are required. This growth has been in step with Gross Domestic Product (GDP) growth, followed by an increased number of vehicles and international travels. Transport depends almost entirely on carbon-intensive fossil fuels; reducing transport GHG emissions will require changes in long-term energy sources. Reducing emissions in the transport sector will require decarbonizing transport energy (International Transport Forum, 2009). The initiative of decarbonizing transport provides decision-makers with tools to identify carbon dioxide ($C0_2$) mitigation measures and, it encourages carbon-free mobility to help fight against climate change. Additionally, decarbonizing transport energy helps governments translate climate ambitions into actions (International Transport Forum, 2020). This translation is done by building a catalog of effective CO_2 mitigation measures.

Decarbonizing transport energy is a way of translating climate commitment into action which involves providing well-identified logical assistance to outline climate actions that could be implemented by countries and partners (International Transport Forum, 2009). However, different decarbonization strategies have technological risks and uncertainties associated with them. For example, an insufficient supply of low carbon technology such as batteries, fuel cells (fuel efficiency) may create side effects on the local environment (IPCC, 2006). In addition, due to technology viability, source of primary energy, and biomass, mitigation from lower energy intensity technologies is uncertain. Furthermore, identifying climate actions involves gathering and sharing evidence for best practices that will quicken the evolution of carbon-free mobility. Also, gathering and sharing evidence could help governments and cities to improve the climate change debate by initiating extensive climate change discussions focusing on global policy dialogue and transport perspectives (International Transport Forum, 2020).

Besides decarbonizing a transport system to reduce transport-related GHG emissions, Bus Rapid Transit (BRT) can be used to mitigate these emissions. BRT's policy involves bus priority measures such as exclusive bus lanes, the private right of way, rapid boarding and alighting, and effective regulations for bus operators, to name a few (McDonnell, Ferreira, & Convey, 2008). Several studies for instance a study by Vincent &Callaghan (2006) indicates that BRT provides significant $C0_2$ reductions compared to light rail transit. The study concluded that BRT is among the best options to alleviate greenhouse gas emissions in the public transport sector (Vincent & Callaghan, 2006).

A study by Winistead & Rogala (2016) indicated that cities such as Curitiba, Bogota, and Guangzhou, China were the forerunners to initiate a way of restructuring urban public transport. The installation of BRT in Bogota was followed by reducing GHG emissions and accidents in public transport (Winistead & Rogala, 2016). Nevertheless, cities in developing countries have been struggling to improve and upgrade the existing transit services at a low cost to imitate the BRT system. This struggle is associated with the challenges that developing countries always face, such as funding and affordability, linking architecture projects with the operational plans, to name a few (Feye, Pabla, & Tutu Benefah, 2014). Several measures are essential to overcome the BRT Challenge and for a successful implementation of the BRT project. Besides, the national government and institutions in the city need to plan and implement BRT actions with care. Therefore, there is a need to improve the coordination of various institutions that are involved in the project planning and implementation. Additionally, political commitment and institutional capacity are critical factors for the success of the BRT project (Feye, Pabla, & Benefah, 2014). Furthermore, overcoming the funding gaps for infrastructure development is essential for a better quality of infrastructure.

In a "business as usual" situation, the rise in the number of private vehicles is expected to increase GHG emissions from the on-road public transport sector to 50% by 2030 (International Association of Public Transport, 2014). On this note, governments should find a way to address the current mobility patterns and avoid the catastrophic climate change that the world is facing nowadays. A way of addressing current mobility patterns includes encouraging the use of public transport as it has the tools to tackle the urban mobility challenges faced by our cities today (International Association of Public Transport, 2014). Instead of constructing a highway and more roads to encourage the use of private vehicles, shifting to public transport would be a way towards emissions reductions. However, vehicle capacity, vehicle efficiency, and fuel types determine public transport's environmental benefits. Households that live near public transportation infrastructure tend to have fewer cars, hence reducing private cars' usage and reduced GHG emissions (Hodges, 2010).

Climate change mitigation options

Transportation of goods and people is a mechanism that relies on fossil fuels and has been the leading global transport model. However, there are challenges and risks associated with this transportation model, such as oil depletion, environmental impacts, and the apparent lack of competition (World Energy Council, 2014). The World Earth Summit on Sustainable Development, held in Johannesburg in 2002, emphasized optimistic relations such as access to energy, eliminating poverty, and improving people's health and quality of life (Earth Summit, 2002).

Improving fuel economy is one way of reducing the impacts of GHGs on climate; it also reduces vehicle fuel consumption (Greene & Plotkin, 2011). A vehicle's fuel economy is given by the distance traveled and the amount of consumed fuel. Generally, governments developed and implemented various fuel economy policies and standards to reduce GHGs emissions (Global Commission on Economy and Climate, 2008). Such policies and standards have been implemented in four large markets, such as the USA, Japan, China, and Europe. Additionally, other significant markets such as Australia, Brazil, India, and South Korea have implemented policies and standards that tend to complement those in broader markets (Greene & Plotkin, 2011).

The vehicle manufacturers claim to determine the fuel consumption level for new cars in the laboratory using chassis dynamometer testing (Goel, Mohan, Guttikunda, & Tiwari, 2015). However, there is a massive difference between laboratory tests and actual on-road fuel consumption. Therefore, there is a gap in the actual world's fuel efficiency and emissions data, especially for developing countries (Venter & Mohammed, 2013). Estimating vehicle emission varies with several factors such as vehicle number, fleet composition, vehicle characteristics, vehicle activities, fuel type, and quality, congestion, driving styles, road type, inspection, maintenance, and vehicle degradation (Goel, Mohan, Guttikunda, & Tiwari, 2015). However, estimating vehicle emissions in sub-Saharan African (SSA) cities such as Kigali involves collecting data on fleet composition, characteristics, and activity for in-use vehicles. Also, there is a need to include the total number of cars disaggregated by vehicle type, fuel type, age, emission technology, and annual mileage (i.e., vehicle kilometers traveled (VKT) per year (Mbandi, et al., 2019). Additionally, in developing countries` data available in-vehicle registries are often unfinished, imprecise, unreliable, and outdated. The gap between fuel efficiency and emission data will be covered in this study by using the IPCC bottom-up approach that provides a higher resolution and detailed data. These data will be collected directly from bus operators, motorcycles, and taxicabs owners/drivers. The owners and drivers understand well their vehicle behavior, especially vehicle fuel consumption, vehicle age, and annual mileage. Therefore, the study will be able to collect updated, finished, and reliable data to estimate emissions.

A study by Ridlington et al. (2005) for Washington, a state of the United States of America, suggested some policy options that can be applied to manage transport emissions. This study stated that a country should adopt the clean cars program by focusing on the year of its production. Additionally, the study indicated there should be an implementation of forceful actions to reduce global warming caused by the transportation sector. Those actions include measures that accelerate the state of the environment such as reducing the rise of vehicle mobility and introducing advanced technology vehicles (hybrid vehicles) (Ridlington, Dutzik, & Schor, 2005).

According to the fourth assessment report of IPCC (2007) non-motorized modes of transport, such as walking and bicycling, are neglected during policy-making in developing countries. However, non-motorized transport modes are emission-free, improve traffic safety in cities and they encourage clean urban transport. In addition, non-motorized transport modes can be a desirable mode of transportation for relatively short distances, which makes up the largest share of trips in cities (Intergovernmental Panel on Climate Change, 2007).

Barriers and limitations to reducing transport GHG emissions in developing

Applying technologies and practices in the transport sectors to reduce greenhouse gas emissions should also be a way of generating social, environmental, and economic benefits (Lah, 2015). However, there are barriers associated with the implementation of the acceptance for low carbon mobility measures; also, shifting to low transport carbon requires extensive efforts from the transport sector. These barriers include lack of infrastructure, lack of capital, insufficient government regulatory support for vehicle emission standards, availability of rail, bus, and other quality transit options, political barriers to public opposition to increased costs (Creutzig, Cruz-Núñez, D'Agosto, & et.al, 2014). For instance, there is a struggle to balance fuel economy improvement, which could lower GHG emissions and advance energy safety and economic activities. Besides, there is a significant challenge of the split intensive between individual cost and economy-wide benefits and they are crucial in the transport sector (Lah, 2015). Because reducing GHG in the transport sector requires higher capital with insufficient payback rates.

Developing countries such as India still face significant challenges towards reducing GHG in the transport sector. For instance, implementing policies to limit trips faces difficulties of enforcement. The institutional structures and governance of a country context play a key role in reducing trips (Zbeida, Clark, & Bartlett, 2014). India possesses a democratic political nature that is based on a republic of states, which makes it hard to enforce the trip limit policy. In contrast, China's decision-making process is more centralized. This has a positive impact on policy enforceability. Lack of adequate public transportation systems in India cause increased GHG emissions, with 30% emissions linked to the transport sector (Pandey, 2017). This increase is linked to the challenges of the city sprawl, which increases transportation requirements. The cities with more significant boundaries will result in higher travel requirements and lead to increased transport-related GHG emissions. Social factors also contribute to user preferences in transport demand, which remains a critical challenge in developing countries. Newly wealthy people in developing countries emulate the car culture, with multiple cars being associated with raised social status (Zbeida, Clark, & Bartlett, 2014). The rising standards of living in developing countries and the fact that their cities are already congested contribute to the increased GHG emissions. In addition, there is still a knowledge gap in the transport sector on behavioral economic analysis and, the relationship between transport and lifestyle (IPCC, 2006). For example, how and when people will choose to use new types of low-carbon transport and avoid making unnecessary journeys is unknown.

In South Africa, introducing green energy or alternative fuel technology for transport as a way towards reducing GHG emissions is a challenge. The private sector has been held back in its long-term investment in CNG and CBG (alternative energy) supply infrastructure due to regulatory uncertainty surrounding the continuance of relative tax benefits of these fuels (Republic of South Africa, 2018). South Africa's government does not set the operative period in the legislation. The uncertainty of the operational period limits the producers to invest in the necessary projects to manufacture biofuels, as they are not guaranteed adequate returns to make a viable financial proposition.

Introducing technology to reduce greenhouse gas emissions in the transport sector, such as electric vehicles in South Africa, is still facing challenges. A social perceptive challenge associated with the prolonged charging times for electric vehicles creates a "range anxiety" for many people and presents a barrier for people to use electric vehicles (Republic of South Africa, 2018). Usually, vehicle owners travel relatively long distances in South Africa.

A consultancy study carried out in South Africa by the Department of Environmental Affairs in 2014, shows that there is a lack of public charging infrastructure, which presents a significant interference to the sector's development. South Africa is still facing challenges in promoting technology and alternative fuel towards reducing greenhouse gas emissions in the transport sector. The challenges of promotion technology and alternative fuel are, among others, that aim to promote green transport stand-alone, hindering the overall effort of improving environmental outcomes in terms of (urban) air quality and mitigating climate change (Department of Environmental Affairs, 2014). There is no high-level, integrated plan that aligns policies and regulations. The lack of integration may hinder the development of a greener transport sector. There is also minimal data gathering on the topic to conduct research and inform policy (Republic of South Africa, 2018).

2.1.2 Transport policy options for public transport in developing countries

Public transport in developing countries faces challenges that sometimes contribute to increased GHG emissions. Challenges faced by developing countries like Latin American and Caribbean regions are law quality public transport, lack of planning, congestion, atmospheric and noise pollution (Berg, Deichmann, Yishen, & Selod, 2017). Population growth is another factor that contributes to the challenges of urban public transport and transport in general, which leads to high travel demand and congestion. In most cases, public transport does not provide full coverage due to the rapid urban sprawls. To respond to these challenges, the different governments implemented transport policies aimed to reduce emissions and promote the use of public transport(Berg, Claudia N.; Deichmann, Uwe; Yishen, Liu; Selod, Harris, 2017) Three elements that determine transport energy use and emissions: the consumed fuel, vehicle characteristics, and kilometer traveled.

The dilemma about transportation policy is to understand market imperfections, for instance, understanding individuals who are unresponsive to changes in fuel price (Pew Center Congressional Policy Brief, 2008). The market imperfections tend to join market forces such as cap and trade programs. Sector-specific policies can be a way of reducing GHG emissions in the public transport sector. These policies should address several objectives at some time such as energy security and GHG reduction goals, a transition to low carbon fuels and alternative vehicle type, alignment of infrastructure, and land use planning with GHG goals (Pew Center Congressional Policy Brief, 2008).

Several policy options that have an important role in reducing greenhouse gases in urban transport could be adopted. The implementation of those policies could be achieved through the technology change that reduces the carbon content per VKT and through the shift from private vehicles to public transit (Safonov, Frenay, & Hecq, 2003). Those policy options include energy pricing, fiscal policy, taxes on transportation congestion pricing. Energy pricing involves charging an economic price based on its carbon content (Button 1993; Goodwin, Dargay, and Hanly 2004). It is a crucial policy instrument that hastens the reduction of greenhouse gases in the long run. Promoting this policy will increase the demand for using transit or public vehicles hence reducing Vehicle Kilometer traveled (VKT). However, if alternative energy such as renewable energy is not available at a reasonable price, energy pricing will not be achieved successfully. This policy is not decided at the local level; it only depends on national policy and increasingly on international agreements.

The fiscal policy instrument is active towards improving fuel economy and reducing fuel use. This options policy is only successful once combined with regulations (Standards & laws) and education (Labeling & advertising) (World Summit on Sustainable Development, 2010). Low carbon fuel standards can be used under the fiscal policy to set goals for reducing the fuel pond life cycle of greenhouse gas intensity in transportation. The instrument allows the manufacturer to make and trades to procure fuels that meet the standards. Those that can reduce their emissions can then generate and sell carbon credits.

Additionally, taxes on transportation fuel can be used as another option to reduce emissions. Charges differ depending on fuel types (e.g., gasoline, diesel, etc.). Linking the taxes to the GHG emissions in monetary value based on a tone of CO_2 equivalent per unit of energy can initiate technological innovation of low carbon (Pew Center Congressional Policy Brief, 2008). Bulgaria has applied this instrument of fuel taxes, and it contributed to the reduction of transport fuel consumption, hence the emissions reductions (World Summit on Sustainable Development, 2010).

Congestion pricing involves introducing a fee for the right to use a certain road and increasing that fee until the anticipated decline in congestion is attained (Safonov, Frenay, & Hecq, 2003). Congestion pricing has some limitations, such as substantial technical investment in its installation and operation. It also has high transaction costs, which might significantly reduce the income of the operators. In 1975 Singapore being a pioneer in accepting congestion charging, the country applied a paper ticketing system for vehicles to access the central zone during peak hours (Pike, 2010). The paper ticketing system was renovated in 1998 to the Electronic Road Pricing (ERP) and the traffic dropped to 31 percent; there was an increase in employment of 33 percent and 77 percent vehicle ownership (Keong, 2010). Consequently, the use of buses raised by 20% due to congestion charging, transit improvement, and related policies (Keong, 2010).

2.1.3 Strategies for promoting the use of public transport in developing countries

Traffic plays a major role in the economy nevertheless, it brings detrimental impacts on the environment; those impacts can fall into three categories, namely: direct threats, indirect threats, and cumulative effect (Sharma & Shiv, 2012). The first category is the direct threats whereby transport imposes an immediate effect on the environment, for instance, noise pollution, the release of carbon monoxide, and carbon dioxide. The second category is the indirect threat where the particulates from transport cause respiratory problems. The last type is a cumulative effect; the emissions from transport contribute to climate change over some time (Sharma & Shiv, 2012).

Promoting public transport use requires a sustainable public urban transport system that permits human beings, businesses, and communities to meet their elementary mobility needs to preserve human and ecosystem health (European Conference of Ministers of Transport, 2004). According to the report by the European Conference of Ministries of transport (2004) urban public transport was defined as a mode of transport that is budget-friendly, well-organized, offers a choice of transport means, and that supports a competitive economy. Also, sustainable public transport was defined as a mode of transport that contributes towards emissions reduction and waste minimization within the earth's capability to absorb them(European Conference of Ministers of Transport , 2004). Besides, sustainable public transport uses both renewable and non-renewable energy at an acceptable rate that minimizes the impacts on the environment.

Promoting public transport requires the integration of transport systems like introducing Bus Rapid Transit (BRT) infrastructure; It makes public transport efficient, affordable, and durable (Hughes & Xianyuan, 2012). A city like Curitiba in Brazil was just like any other city before 1960 until a master plan was adopted in 1968 to implement different strategies (World Resources Institute, 2011). The strategies implemented included: several innovative systems to create jobs, improve public transportation accessibility, promote housing development, and improve waste management. Hence, Curitiba city is now considered one of the greatest sustainable cities in terms of urban public transportation (World Resources Institute, 2011). Implementing innovative systems on public transport in Curitiba has increased the number of passengers in public vehicles up to 28% and it has driven congestion down by 25% and 30% reduction in fuel consumption (Soltani & Ehsan , 2012).

Some regions such as Latin America and the Caribbean agreed on tangible targets, they also adopted the agreement on the need to expand renewable energy resources and to increase the percentage of energy produced from renewable sources (Earth Summit, 2002). These countries embraced technological solutions such as alternative fuels like biofuels and intelligent transport systems (ITS); for instance, in Costa Rica, 40% of their emissions are from public transport, therefore the country introduced electric cars to reduce their emission (Irfan, 2018). Additionally, to address environmental problems such as noise and air pollution, oil dependency, and traffic congestion; technology in transport has been proven to help in reducing those environmental problems (Pojani & Dominic, 2015).

2.1.4 Overview of Urban Public transports in Kigali city, Rwanda

Parallel to the increasing population in Kigali city as shown in Figure 1.1, there was an increase in gas emissions due to the increased number of vehicles and it affected the quality of air in Kigali city (Rwanda Transport Development Agency, 2012). Additionally, pollution from industries, home cooking, soil, dust, and waste burning were among other factors that may have contributed to deteriorating the air quality (Biruta, 2018). Furthermore, the increase in greenhouse gases was associated with the rapid increase in high vehicle density as shown in Table 4.5, the use of older vehicles, and lack of maintenance facilities (Nsengimana, Bizimana, & Sezirahiga, 2011).

Various studies conducted by the Rwanda Ministry of Health revealed the consequences of air pollution from transportation on human health in Kigali city, such as a study that focused on respiratory illness in 2009. Also, sustainable management of Kigali city called for complete measures to address vehicle emissions and to reduce the increasing air pollution and human adverse health effects (Rwanda Environmental Management Authority, 2009).

A study by Sudmant (2017) measured transport emissions in Kigali and analyzed the influence of low carbon urban actions on emissions in Kigali. The study indicated a rapid increase in energy use in the transport sector, energy expenditure, and greenhouse gases by 9%, 19.7%, and 8.9% respectively, during the period

2000-2015 (Sudmant, Colenbrander, Gouldson, & Chilundika, 2017). The increase indicated that the transportation sector increased at a high speed of any sector in the city, followed by the building sector (8.1%) and the waste sector (6.4%) (Sudmant, Colenbrander, Gouldson, &Chilundika, 2017). Additionally, the study showed that the development of the business as usual scenario projected that energy use, energy expenditure, and emissions are expected to continue to over grow to 2032 by 6.4%, 6.3%, 8.6 % per annum, respectively (Rwanda Transport Development Agency, 2012). Furthermore, the study concluded that there are increased opportunities for the private sector to invest in low-carbon transition and it will give the city a better direction away from business as usual pathways (Sudmant, Colenbrander, Gouldson, & Chilundika, 2017).

Rwanda's public transport challenges

Rwanda managed to have to develop transport infrastructure recently yet public transport kept facing challenges. The country had challenges to provide adequate transport services; as it was difficult to provide people and goods' door-to-door mobility (United Nations, 2017). In 2015 the Ministry of Infrastructure assessed the existing public transport in Rwanda and, it elaborated on the challenges related to public transport, such as insufficient support to meet the public transport demand, deteriorated road surface, lack of coordination between different policy-making, regulatory, and implementing agencies (Mbonyinshuti, 2018). The study by the Ministry of Infrastructure elaborated fundamental strategies to address transportation challenges, reducing traffic congestion, energy use, and pollution. Although the study didn't estimate GHG emissions from public transport, proposed possible measures to reduce traffic congestion and energy use challenges were elaborated.

A study by Niyonsenga (2012) using performance assessment analyzed public transport network routine and service capacity about the potential transit demand in Kigali. Also, GIS (Geographical Information System) techniques were used to develop a system-level performance measurement that assessed service availability in different city locations. Furthermore, the study indicated that 37% of the market is sufficiently served; also, the study showed that 65% of the potential demand could be served regardless of the distance required to reach the bus stops (Niyonsenga, 2012). It was noted in the study that the low performance in public transport was due to deficiencies in the public transport route network and service capacity constraints (Niyonsenga, 2012). The study gave a deep understanding of Kigali public transport performance and route-wise customer satisfaction. However, the study did not estimate public transport GHG emissions. Conversely, this study will estimate GHG emissions from Kigali public transport and propose possible mitigation measures.

Vehicle emission and mitigation measures in Rwanda

A study by the Rwanda Ministry of Environment (2018c) indicated that the most important contributors to air pollution in Rwanda are vehicle emissions and biomass energy from domestic cooking. The study called for responsible structures to find alternative energy for cooking and called for enforcement of vehicle emissions inspection to reduce pollution from vehicles. In addition, the study indicated that in 2018 the average age of cars in Rwanda was 19 years, with more than half of the vehicles made before 1999, and 95.2 percent of vehicles were more than ten years old, which explains why they are the primary pollutants (REMA, 2018c). The study recommended that different stakeholders could work together to limit the importation of older vehicles in Rwanda. It also suggested that there was a need to enforce vehicle emissions inspection to reduce pollution from cars and to command a willingness study in Rwanda to adopt electric vehicles in its transport fleet policy (REMA, 2018c).

Rwanda has been promoting non-motorized transport through the construction and renovation of walkways, and up to 10% of Kigali trips are non-motorized trips, and 70% are public transit (Nkurunziza, 2018). Kigali city's journey towards reducing GHG and promoting public transport use has been improved drastically. A report by Nkurunziza (2018a) indicated that twenty-two new routes were created over forty-one preliminary routes; also bus stops and existing routes were extended to reduce the walking distance to the nearest bus stops and, to reach residential areas. Additionally, four zones were formed: KBS -Zone I, Royal-Zone II, RTF-Zone III, and RFTC-Zone IV to organize public transport service and each transport zone had a dedicated operator who is held responsible in case of any raised issues like poor service delivery (Nkurunziza, 2018b). Also, bus operators purchased bigger busses to replace smaller minibusses and these minibusses shifted to serving in minor routes. In addition, internet and e-ticketing were introduced based on the existing fiber internet spread (Nkurunziza, 2018a).

Bus management services introduced a queuing system to improve passenger safety and order at the bus stops and bus terminals and some terminals were renovated to facilitate route loading and unloading (Nkurunziza, 2018b). Although pathways will ease the demand on the roads, the number of private cars and motorcycle journeys increased rapidly due to the growth of the Kigali population. Many people are using the motorcycle in Kigali, and they are expensive compared to the buses and not safe; this shows how the Kigali bus sector is working well below capacity (Bajpai, 2014). According to the 2013 MININFRA report, out of 118,656 vehicles registered in Rwanda, 48.86% are motorcycles. The report predicted that the emission from motorcycles was the main contributor to the total greenhouse gas emission in the transport sector (MININFRA, 2013). Therefore, the change in regulations might deliver improvements in Kigali bus services hence reduce GHG emissions.

Rwanda's GHG emission baseline in the transport sector

According to the initial, second, and third national communication to the UNFCCC, the baseline trends in GHG emissions in Rwanda from the historical emissions trends from 1990 to 2015; the baseline years 2002, 2005, and 2012 were chosen. In the year 2002 energy sector dominated in $C0_2$ emissions by 92%, followed by land use and forestry with 7% and, CO_2 emissions from the transport sector were 259.68 Gg and 0.04173 Gg of CH_4 (REMA, 2005). In 2005, measures taken towards reducing GHG emissions and promoting efficiency in the transport sector included, among other things, improving the importation of new vehicles with low fuel consumption through loan access and decreased taxes on cars aged less than five years. Additionally, they encouraged public transport through incentive tariffs (REMA, 2005).

For the year 2005, the baseline year, GHG inventory shows that Rwanda has contributed to the emissions of 530.88 Gg of CO_2, 71.31Gg of CH_4, and 10 Gg of N_20 under the energy sector (REMA, 2006). In 2005, the emission from the Transport sector was 269.9 Gg of $C0_2$. Mitigation measures were taken towards reducing greenhouse gas emissions in the transport sector. The government of Rwanda formulated regulations on the quality of imported vehicles taking into account the year of manufacture, the mileage, and other technical characteristics required. Additionally, regulation on direct vehicle GHG emissions measurements and promoting public transport was formed (REMA, 2006). The baseline year 2012 indicated that the emission from the energy sector was 1,343.16 Gg of $C0_2$ under which the energy sector had emissions of 458.29 Gg of CO_2 (REMA, 2018c). Among the greenhouse gas emissions from the transport sector, $C0_2$ emissions were dominant, followed by CH_4 and N_20 with 54.85%, 37.12%, and 8.03%, respectively (REMA, 2018c). The government of Rwanda took the mitigation measures of adopting electric cars combined with fuel efficiency.

Table 2.1 Summary of literature review

List of authors, references resources	Key aspects, concepts, elements covered by the study	List of research methods used	Knowledge gaps (that justifies the research problem)
T V Ramachandra and Kashyaq Shwetmala, 2009	-The study looked at road transport, rail, and ship emissions in general in different states of India Transport emissions of CO2, CH4, CO, NOx, N2O, SO2, PM, and HC	IPCC Top-down approach	The study does not focus on urban public transport emissions in particular.
Ison S.G and Ryley T., 2007	Estimated the emissions from public transport, including Rail in the United Kingdom (UK), and proposed policy options for sustainable public transport	IPCC Top-down approach	The study didn't use actual emissions. Emissions were estimated based on energy consumption allocation.
Adriana Mutheu Mbandi et al., 2019	Estimated on road transport emissions in Nairobi for both formal fleet (private cars, motorcycles, light and heavy trucks) and informal fleet(matatus and bodabodas)	IPCC Bottom-up approach	The study does not propose possible mitigation options for promoting sustainable use of urban public transport

Mbonyinshuti, 2012	- The study looked at the challenges facing all public transport in Rwanda	Social survey	The limited literature on GHGs emissions.
David Niyonsenga, 2012	- Public transport performance in Kigali city -Route wise customer satisfaction	GIS techniques	-The study didn't look at public transport emissions

2.2 Conceptual framework

The research applied the conceptual model of the urban ecosystem management model; as proposed by Dakhia & Berezowska (2016). The conceptual framework was developed to assess and monitor the progress towards the sustainability of an urban built environment (Dakhia & Berezowska, 2016). The author surveyed other urban frameworks such as the IIED (International Institute of Environment& Development) 3-tier framework on urban environmental problems in developing countries, DPSR (Driver, Pressure, State, Impact, and Response) framework, and Deep ecology framework but they were not used for the study. These frameworks were not used in the study because they lacked the aspect of regulation function which emphasizes policy and climate change mitigation measures.

The urban ecosystem management framework illustrates anthropogenic activities, transport being an internal flow and a service on a built environment; an increase in public transport use is the input, and waste and emissions are the outputs. This framework is chosen over other frameworks that speak to urban management because it draws our attention to how human society and structure affect natural systems and the quality of human life. The framework is based on the principles which are delivered from the natural ecosystem function. Those principles include carrying capacity, feedback, integration, adaptability, diversity, synergy, and elegance (Environment, beauty), leading to a straightforward model to comprehend. Additionally, these concepts which are used in this framework can easily be translated into action in terms of the policy to improve urban environmental management (Dakhia & Berezowska, 2016). In addition, the framework shows how reduced emissions could result in the implementation of Sustainable Development Goals (SDGs) such as SDG 3 (aspires to ensure health and well-being for all), SDG 6 (Ensure access to water and sanitation for all. Water and Sanitation), SDG 7(enhance international cooperation to facilitate access to clean energy research and technology), SDG 11 (cities and human settlements inclusive, safe, resilient, and sustainable) and SDG 13 (Take urgent action to combat climate change and its impacts.)

The urban ecosystem management framework has the potential to link the urban environmental management themes such as urban biodiversity and natural features, pollution management, ecosystem service enhancement, and natural hazards. The framework creates urban sustainability, resilience, and infrastructure initiatives, increasingly reshapes cities, and elevates a consideration of proposed actions (Brown, 2017). Besides the strengths of this framework, there are limitations associated with it. The urban ecosystem management framework does not articulate the political, economic, and policy role, which is the primary driver of urbanization and environmental change associated with it. Additionally, it does not consider and deal with urban land use or spatial dimensions of urban development (Dakhia & Berezowska, 2016). These limitations are addressed in chapter 2 in the literature review under the transport policy options subtopic. Also, others limitations were addressed under data collection and methodology in chapter 3 and chapter 4.

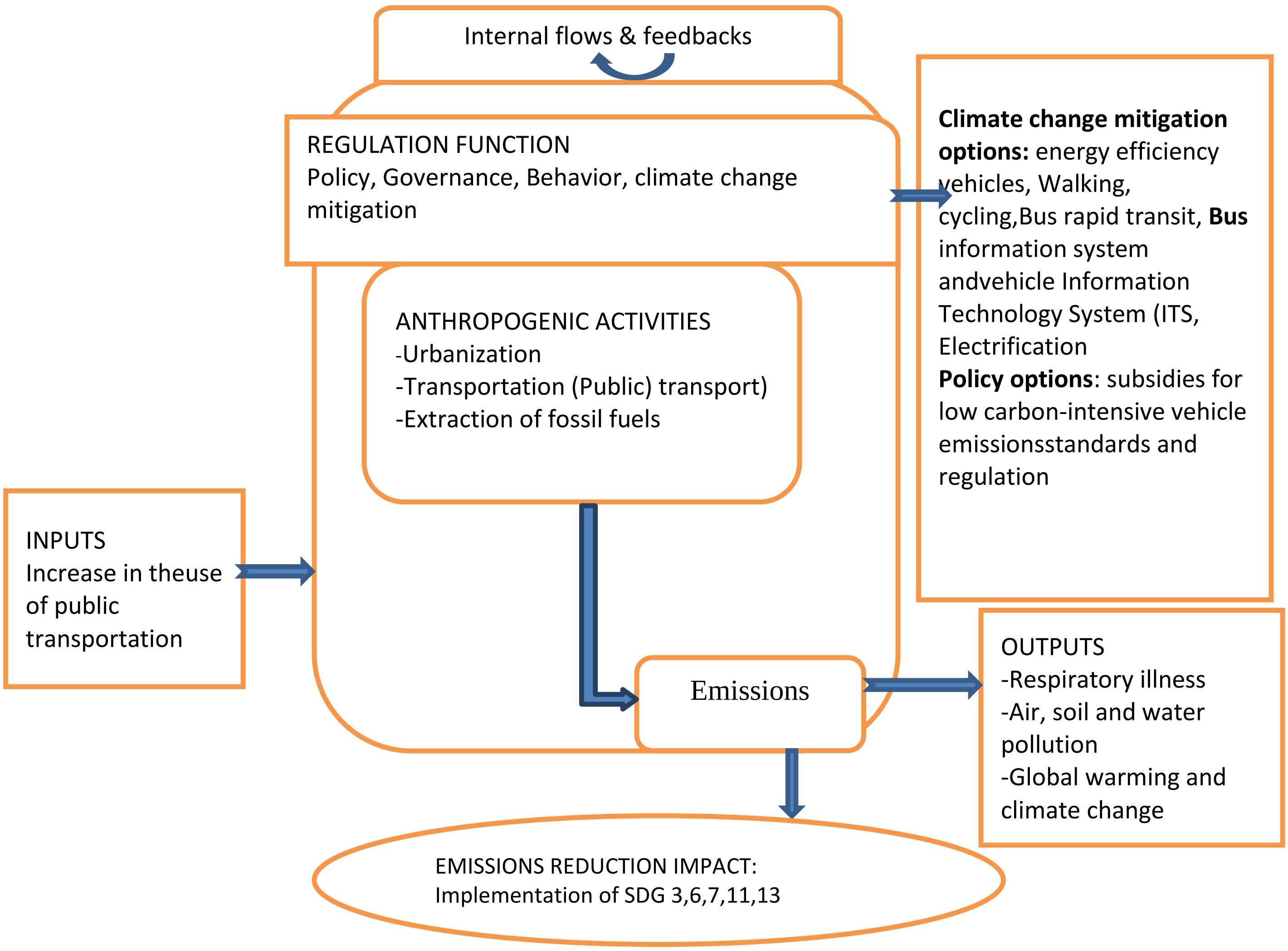

Figure 2.1 Conceptual framework: Adopted and modified from "Towards an urban ecosystem sustainability assessment tool" report by Dakhia & Berezowska (2016)

2.3 Summary and Conclusion

This chapter discussed different studies that focus on emission reduction and transport policy options in public transport for various developed and developing countries. Despite the research findings made for different governments to adopt, some countries still have challenges in implementing sustainable urban public transport policy. A discussion showed that mitigating the climate impacts of GHGs was to reduce the growth of vehicle fuel consumption by improving fuel economy.

Also, this chapter identified a vital knowledge gap, which is a difference between the laboratory tests and the real-world fuel emissions data, especially for developing countries. The difference implies that the vehicle manufacturers claim to determine the fuel consumption level for new cars in the laboratory using a chassis dynamometer. However, there is a huge difference between the laboratory tests and the actual value of on-road fuel consumption. Hence this study shall consider the actual on-road fuel consumption to estimate GHG emissions from Kigali's public transport. Additionally, this chapter highlighted the conceptual framework, the urban ecosystem management framework. The conceptual model of the urban ecosystem management model adopted was proposed by Dakhia & Berezowska (2016). It has been developed to assess and monitor the progress towards the sustainability of an urban built environment. The next chapter elaborates on the methodology and research design that were used in this study.

CHAPTER 3: RESEARCH METHODOLOGY

Overview

Chapter 2 reviewed several studies of emission reduction options and policy options in public transport. Also, the chapter discussed emission reduction dimensions and their influencing factors to identify the critical knowledge gaps. The framework also highlighted the conceptual framework, which explained in narrative form the keywords. This chapter described the methods, research design, and instruments that were used to collect data for this study. In addition, the chapter demonstrated how the findings were analyzed and presented. It also discussed research ethics, validity, and reliability.

3.1 Research design

The research used a mixed-method approach for collecting both quantitative and qualitative data. The study used three different methods, namely: IPCC methodology (Intergovernmental Panel on Climate Change) which was used as a principal method, documentary analysis, and key informant methods were used as complementary methods. Figure 3.1 below shows the research designs from data collection to reporting.

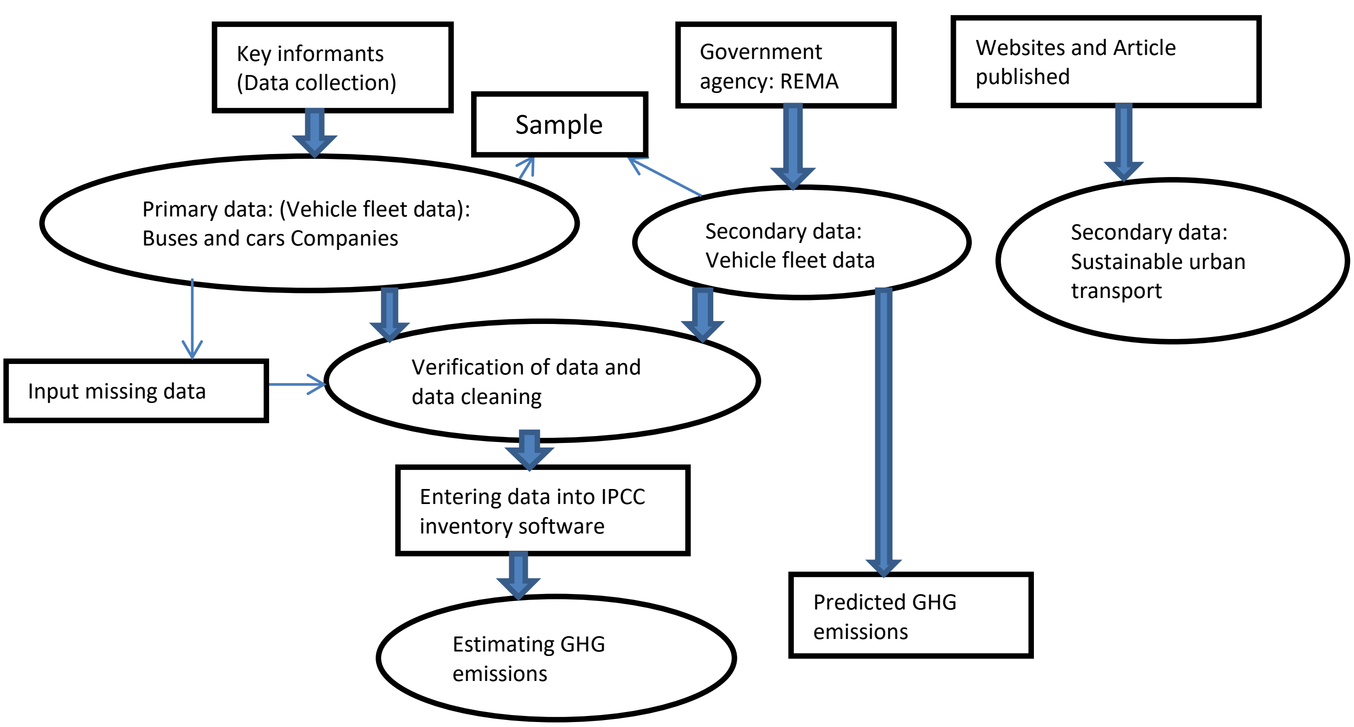

Figure 3.1 Research designs from data collection to reporting

Source: (Mbandi, et al. 2019)

3.1.1 IPCC Tier 1 method

Tier 1 method is one of the Intergovernmental Panel on Climate Change methodologies (IPCC). It uses default country emission factors, which are estimated based on the parameters that are more appropriate to the forests, climatic regions, and land-use systems in that particular country (Intergovernmental Panel On Climate Change, 2006). The amount of GHG emissions caused by motorized transport depends on the extent of transport activities. This approach is a correct approach to use as it does not skip over the activity data (Plotkin, 2004). Transport activity refers to the physical movement of vehicles, and it is measured in vehicle kilometers traveled, VKT, and fuel consumed (Bongardt, Eichhorst, & Dünnebeil, 2016). IPCC Tier 1 method uses default emission factors, while other IPCC methods use country-specific fuel carbon contents. Rwanda does not have specific fuel carbon contents; this is why IPCC tier 1 will be used for the study. Additionally, the IPCC tier 1 methodology overlooks the time taken by the vehicle to travel (Congestion time) because the time is only considered when the country's fuel carbon content is known.

The method uses IPCC inventory software to estimate emissions. The purpose of this software is to implement Tier1 and Tier 2 methodologies in the 2006 IPCC Guidelines to prepare national GHG inventories according to the 2006 IPCC Guidelines. The primary target groups of users are inventory compilers for applying default 2006 IPCC guidelines, methods, on national GHG inventory compilation (IPCC task force, 2017). The basic approach of the software is to enable filling out the 2006 IPCC guidelines category worksheets with the activity and emission factor data. It also supports many other functions related to database administration, quality control, data export/import, and data reporting. Figure 3.2 shows the basic inventory data relation of the IPCC software.

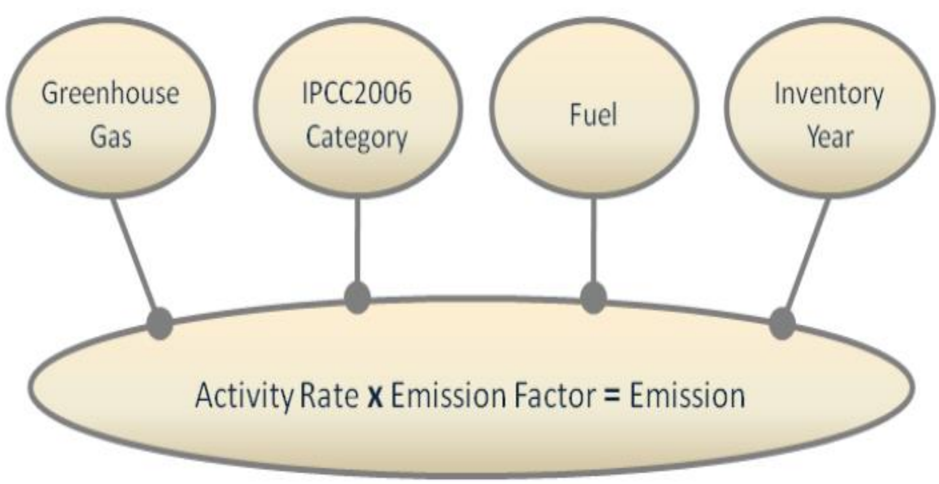

Figure 3.2 Basic inventory data relations

Source: IPCC task force (2017)

The graph above shows how on-road transport GHG emissions are estimated from the IPCC inventory software. The activity rate refers to the vehicle activity data, which is estimated either by Vehicle Kilometer Travelled (VKT) or by fuel consumed.

Steps in estimating emissions from road transport

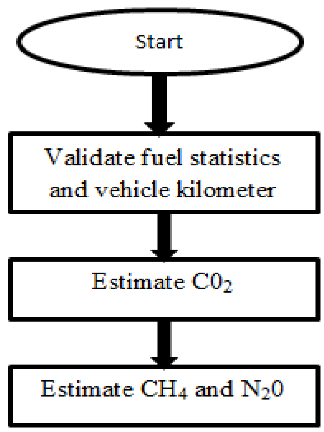

Figure 3.3 Steps in estimating emissions from road transport

Source: IPCC (2006)

There are three steps involved in estimating emissions from road transport:

1st step: Validating Fuel Consumption (VFC)

$$Estimated\ fuel = \sum_{i,j,t}[Vehicles_{i,j,t}.Distance_{i,j,t}.Consumption_{i,j,t}] \quad (1)$$

Where:

Estimated Fuel = total estimated fuel use from a distance traveled (VKT) data (l)

Vehicles i, j, t = number of vehicles of type i and using fuel j on road type t

Distance i, j, t = annual kilometers traveled per vehicle of type i and using fuel j on road type t (km)

Consumption, j, t = average fuel consumption (l/km) by vehicles of type i and using fuel j on road type t

i = vehicle type (e.g., car, bus)

j = fuel type (e.g. motor gasoline, diesel, natural gas, LPG)

t = type of road (e.g., urban, rural

2nd step: Estimating $C0_2$Emissions (ECOE)

$$Emission = \sum_a(Fuel_a.EF_a) \quad (2)$$

Where:

Emission = Emissions of CO_2 (kg)

$Fuel_a$ = fuel sold (TJ)

EF_a = emission factor (kg/TJ).

a = type of fuel

(E.g. petrol, diesel, natural gas, LPG, etc.)

The table below shows the $C0_2$ default emission factors for different types of fuel

Table 3.1 $C0_2$ Default emissions factor

Fuel type	Default (kg/Tj)
Motor Gasoline	69,300
Gas/Diesel Oil	74,100
Liquefied Petroleum Gases	63,100

Source: IPCC (2006)

3rd step: Estimating CH_4, N_20 Emissions (ECHNE)

$$Emission = \sum_a [\,Fuel_a . EF_a] \quad (3)$$

Where:

Emissions = emission in kg

EF_a = emission factor (kg/TJ)

$Fuel_a$ = fuel consumed, (TJ)

(As represented by fuel sold)

a = fuel type a (e.g., diesel, gasoline, natural gas, LPG)

The table 3.2 shows CH_4 and N_2O default emission factors for different types of fuel.

Table 3.2 CH_4 and N_20 default emissions factor

Fuel type	CH_4 default (kg/Tj)	N_20 default (kg/Tj)
Motor Gasoline	33	3.2
Gas/Diesel Oil	3.9	3.9
Liquefied Petroleum Gases	62	0.2

Source: IPCC (2006)

The default emission factors are estimated based on the parameters that are more appropriate to the forests, climatic regions, and land-use systems of a country (IPCC, 2006). Also, default emission factors used for national inventory have their uncertainty ranges based on a country's circumstances. However, some countries (Developed or developing countries) have specific emission factors that can be found in the IPCC Emission Factor Database (EFDB) (Shermanau, 2019).

This method helped provide information for the following questions: 1.1 what is the estimated quantity of GHG emissions from public transport in Kigali? 1.2 Which public transport modes contribute more to the GHG emissions in Kigali?

3.1.2 Population

This method covered public transport vehicles that operate in Kigali city, which consists of buses, taxicabs, and motorcycles. According to RURA's transport sector report of 2018, Kigali city had 352 buses, 600 taxicabs, and approximately 15,000 motorcycles. The following equation(4) was used to find the sample size. The overall n in equation 4 will be given by the summation equations (5), (6), and (7).

$$n = \frac{N}{1+Ne^2} \tag{4}$$

$$n1 = \frac{600}{1+600(0.1)^2} = 86 \tag{5}$$

$$n2 = \frac{352}{1+352(0.1)^2} = 78 \tag{6}$$

$$n3 = \frac{1500}{1+1500(0.1)^2} = 99 \tag{7}$$

n= 86+78+99= 263

Where n equals sample size, N equals public vehicle number, and e equals marginal error, which is 10%. The confidence level for the sample size is 90%. As described in chapter 1 the city of Kigali had three districts namely: Nyarugenge, Kicukiro, and Gasabo, and each district had one bus Company, one taxicab union, and one motorcycle union. Each union had different cooperatives depending on the number of taxicabs or motorcycles in that district. In total Kigali had 3 bus companies, 52 motorcycle cooperatives, and 48 taxicabs cooperatives. The clusters were formed based on cooperatives and companies, and clusters were randomly selected to use as samples. With cluster sampling, the sample size for vehicles where population equals 600, the sample size (n_1) is 86 taxicabs as shown in equation (5). Buses sample size where population equals 352, the sample size (n_2) is 78 as shown in equation (6). Motorcycle's sample size where the population equals 15,000 the sample size (n_3) is about 99 as shown in equation (7).

Therefore the overall sample size (n_1+n_2+ n_3) from equation (4) for Kigali public transport is 263 public vehicles. The advantage of this formula is to provide confidence limits of the sample size**.**

3.1. 3 Data collection and recording instruments

The IPCC research method is a primary source of data collection. Stratified random sampling was used with the method and strata were formed from each vehicle category and were grouped based on vehicle age and vehicle mode, and data were randomly collected from each stratum (Taherdoost, 2016). Data were collected using questionnaires (See annex 5) to collect data on fuel consumption, car type, and kilometers traveled. Buses and cars used electronic ticketing; this helps the cooperatives to store data electronically, such as kilometers traveled and fuel consumed. The questionnaire (see annex 5) was prepared for collecting data about other transport activities for the buses and car models. Collected data were recorded into papers and copied in an excel sheet format for proper storage (Abawi, 2013). This method generated quantitative data. Table 3.3 shows the data for the transport and the type of activity data that were collected. In general, the use of fuel consumed is appropriate for CO_2, and the distance traveled by vehicle type is appropriate for CH_4 and N_2O (IPCC, 2007). Vehicle activity data were collected for the activity done fully inside a Kigali city, and traffic situations were not considered for the study.

Data set 1 was available from car companies because they are the kind of data kept in these organizations.

Data set 2 was available from bus companies and motorcycles federation because they are the kind of data kept in these organizations.

Data set 3: was obtained from both car and bus companies.

Table 3.3 data source for transport Activities

Data Source	Means of transportation	Kind of activity data	System boundaries	Traffic situation
Vehicle activity survey	Public vehicles (Taxicabs, Buses)	Per vehicle: Data set 1:VKT or - number of trips and distances (Car companies) Data set 2: VKT from odometer (Bus companies and motorcycle federation) Data set3: Fuel Consumed (Bus and car companies)	Territorial: boundaries of the Kigali city	Optional: Traffic situations are only possible with linkage to GIS data of the road network

Source: Bongardt, Eichhorst, & Dünnebeil (2016)

3.1.4 Strengths

The IPCC Tier 1 method has been used in several types of research as it does not skip activity data (Lopez-Aparicia, Vogt, & Thank Vo, 2015). It is accurately used when the boundaries are set for the study, for instance, territory boundaries such as a city. A bottom-up approach was used to determine the transport emissions statewide in India for the road transport sector in India (Ramachandra & Shwetmala, 2009). The research carried in Tehran, the capital city of Iran when estimating traffic-related CO_2 from motor vehicles, used it. The approach helped identify emissions from different modes of transport, including buses, taxis, private cars, and motorcycles. The study's outcome gave Tehran guidance on how it can mitigate emissions from transport. The study provided an estimate of how much fuel is consumed and the average CO_2 emitted from the transport sector (Kakouei, Idris, & Vatani, 2012).

3.1.5 Limitations

The IPCC tier 1 approach requires much effort in data collection. The calculation of GHG emissions directly does not refer to the fuel consumption of national statistics (Intergovernmental Panel on Climate Change, 2006). It only focuses on the actual value of the fuel consumed by vehicles, which are obtained from company reports. During data collection, the rise of uncertainty might appear, for instance, lack of completeness and misclassification of fuel. This weakness was addressed by collecting data from company management and the Rwanda Environment Management Authority (REMA) to ensure data accuracy. The compilation involved a comparison between the estimated emission using both the fuel statistics and vehicle kilometer traveled data (IPCC, 2006). Any anomalies between the emission estimates were investigated and explained.

3.2 Documentary Analysis

A documentary analysis method is a form of qualitative research that involves reviewing or evaluating both printed and electronic documents. Documents are interpreted by the researcher to give voice and sense about the topic being studied. This method provides background information and historical insight into the study. This information and insights help to understand the historical root of the specific issues such as the causes of GHG emissions from public transport under the study, hence providing the right solutions (Bowen, 2009).

This method helped in providing information for the following questions: 2.1 what are the climate change mitigation measures for urban public transport? 2.2 Which political, environmental, and economic instruments could assist in reducing emissions in urban public transport in Kigali?3.1 Which transport policy measures can be adopted for urban public transport to minimize GHG emissions?

The document analysis method is a secondary source of data collection. This method involved the use of published and unpublished documents. Non-published documents consisted of institutional and company reports, and published documents were obtained from government publications and earlier research published on the internet. Different countries published documents related to the study both developed and developing countries. Cluster sampling was used in the study where clusters were formed based on geographical region and samples were selected using random sampling (Taherdoost, 2016). Furthermore, data were recorded in a soft copy format using a computer, and it generated both quantitative and qualitative data (Abawi, 2013).

3.2.1 Strengths

Documentary analysis is a time-efficient and cost-effective method as it is less time-consuming and less costly than other research methods. This method is an attractive option for researchers because data are easily accessed through the internet, and in most cases, without the author's permission. Additionally, the use of documents provides broad coverage in terms of the long period, many events, and many settings (Bowen, 2009).

3.2.2 Limitations

This method has limitations like any other method. It cannot provide the organization's day-to-day operations; in other words, it provides insufficient details. Also, it’s not always easy to access some data because access to some documents might be blocked deliberately (Bowen, 2009). The limitations were addressed by interviewing key informants involved in the day-to-day operations of different transport companies. Additionally, the limitations were addressed by comparing published data from different government institutions responsible for the matter under the study.

3.3 Key Informants method

The key informants' method comprises interviewing people who are particularly informed and have perspectives on an aspect of the study. This method is suitable for the study as it provides clarity of ideas and information and provides an in-depth understanding of the topic of interest.

This method helped provide information for the following questions: 3.2 To what extent have formulated transport policies for urban public transport been implemented in Kigali?4.1 How have recent innovative initiatives and best practices for promoting urban public transport have been implemented? 4.2 What are the barriers and limitations to promoting the use of urban public transport in Kigali?

3.3.1 Population

This method involved interviewing employees of the different government institutions (Ministries/Agencies). Rwanda had 19 ministries with different affiliated agencies such as the Ministry of Education, Ministry of Agriculture, Ministry of Defense, Ministry of Foreign Affairs, Ministry of Environment,….The interviewees were from five governments institutions, namely Rwanda Utility Regulation Authority (RURA), Ministry of Infrastructure (MININFRA), and Rwanda Environment Management Authority (REMA) City of Kigali (CoK), and Rwanda Transport Development Agency (RTDA). These institutions were chosen among others because they are the direct stakeholders when it comes to public transport and emissions from the transport sector. These institutions provided confidential, in-depth information about the subject matter.

3.3.2 Data collection and instruments

This research method is the primary source of data collection. Data were gathered through structured and unstructured interviews. Additionally, data were recorded on paper, later on, copied in a flexible format.

3.3.3 Strengths

The main advantage of the key informant's method is that data can be obtained quickly. This method allows the researcher to get the expert-level perspective. The method also provides in-depth ideas and information about the topic of interest (Marshall, 1996). Besides, the key informants' method helps a researcher frame a preliminary understanding of the study by providing the case background for the matter under the study.

3.3.4 Limitations

Identifying the appropriate key informants is one of the limitations of this method; it also takes time to select those key informants and build trust. The informants might give their impressions and biases. Another limitation is that the key informants might only provide political acceptable perspectives (Marshall, 1996). The researcher worked in the Rwandan transport sector for 3 years before carrying out the study; this facilitated the researcher to identify the appropriate key informants for the study. Also, the limitations were addressed by applying for the research permit from the National Commission of Science and Technology; this gave the researcher credibility to get all the data. Additionally, before collecting any data the researcher took some time to explain more about GHG emissions and how the data shall be used. The explanation reduced the bias from the key informants given that it was academic research.

3.4 Data collection and data analysis

This study collected quantitative and qualitative data; qualitative data were collected through semi-structured questionnaires, interviews with key informants, and document analysis. The questionnaires were stored in excel sheets for better usage during data analysis. Qualitative data collected provided the researcher with an in-depth analysis of subject matters, and quantitative data collected can be used in concluding the subject matter. Qualitative data provide an analytical and logical interpretation of conclusions drawn from quantitative data; this shows how they complement each other. The reason being that qualitative data lack reliability; quantitative data lack description. That is why they are used in conjunction so that the data gathered are free from any errors (Surbhi, 2016).

Content analysis is a research tool used to analyze the presence, meanings, and relationships of words and concepts, making inferences about the messages within the texts (Elo& Kyngas, 2007). The application of content analysis involves using three approaches, such as conventional, directed, or summative approaches (Hsieh & Shannon, 2005). All three approaches are used to interpret meaning from text data content to follow a realistic pattern. The content analysis was used to analyze three variables: policy, sustainable public transport, and climate change mitigation. The analysis involved coding categories that were derived directly from the text data such as availability, time spent in travel, comfort, etc.… As described in chapter 4. Also, the content analysis involved the use of a theory or relevant research findings as guidance for initial codes. In addition, summative content analysis involves counting and comparing keywords or content, followed by the interpretation of the fundamental context (Hsieh & Shannon, 2005).

Simple linear regression analysis, a strong statistical method, was used to predict variables (Mooi, 2014). Two variables were used in the study, the number of vehicles as an independent variable and GHG emissions quantity as a dependent variable. Table 3.4 shows the research methodology and data analysis. Table 3.5 shows the operationalization of variables. It is highlighting the essential components that assisted in carrying out data collection and data analysis.

Objectives	Research question	Variables	Units of measurements	Research methods	Data analysis	Expected outcomes
1.To estimate GHG emissions of urban public transport in Kigali from 2012 to 2019	1.1 What is the estimated quantity of GHG emissions from public transport in Kigali?	Public transport	Emission of GHGs	IPCC Inventory software 2006: IPCC tier 1 (Bottom-up approach)	Simple linear regression analysis	Estimated GHG emissions
	1.2 Which public transport modes contribute more to the GHG emissions in Kigali				IPCC software analysis	Vehicle category that contributes to more GHG emissions
2.To identify GHG emissions reduction options for urban public transport in Kigali	2.1 What are the climate change mitigation measures for urban public transport? 2.2 Which political, environmental, and economic instruments could assist in emissions reduction in urban public transport in Kigali?	Climate change mitigation	Emissions reduction	Documentary analysis Key informant	Content analysis	Climate change mitigation measures
3.To determine transport policy options for urban public transport in Kigali	3.1 Which transport policy measures can be adopted for urban public transport to minimize GHG emissions? 3.2 To what extent have formulated transport policies for urban public transport been implemented in Kigali?	Policy	Change in behavior	Documentary analysis Key informants	Content analysis	Regulatory policies are determined Level of implementation
4. To explore strategies for promoting the use of public transport in Kigali	4.1 How have recent innovative initiatives and best practices for promoting urban public transport been implemented? 4.2 What are the barriers and limitations of promoting urban public transport in Kigali?	Sustainable public transport	Sustainability	Key informants Documentary analysis	Content analysis	Barriers and limitation Innovative initiative and good practices

Table 3.4 Research methodology and data analysis

Table 3.5 operationalization of variables

Objectives	Key Research Question	Variables	Dimension of variables	Elements of attributes	Research methods	Type of data	Indicators
1. To estimate GHG emissions of urban public transport in Kigali from 2012 to 2019	1.1 What is the estimated quantity of GHG emissions from public transport in Kigali? 1.2 Which public transport modes contribute more to the GHG emissions in Kigali?	Urban public transport	Emission of GHGs	Vehicle kilometer traveled,	IPCC tier 1	Quantitative	Fuel consumption, Fuel price, Length of public transport roads
				Vehicle activities	IPCC tier 1	Quantitative	Number of trips, number of stops, working hours, peak hours
2.. To identify GHG emissions reduction options for urban public transport in Kigali 3. To determine transport policy options for urban public transport in Kigali	2.1 What are the climate change mitigation measures for urban public transport? 2.2 Which political, environmental, and economic instruments could assist in emissions reduction in urban public transport in Kigali? 3.1 Which transport policy measures can be adopted for urban public transport to reduce GHG emissions? 3.2 To what extent have formulated transport policies for urban public transport been implemented in Kigali?	Policy and climate change mitigation	Emissions reduction Change in behavior	Land use planning	Documentary analysis	Qualitative	Bus rapid transit (BRT), Congestion reduction
				Public transit	Key informants	Qualitative	Walking, cycling, Bus rapid transit, Bus information system, and vehicle Information Technology System (ITS)
				Fuel Economy	Documentary analysis	Qualitative	Low carbon technology, Information to reduce unneeded mobility,
				change in attitudes	Key informants	Qualitative	subsidies for less carbon-intensive means of transportation, vehicle emissions standards, and regulation
4. To explore strategies for promoting the use of urban public transport in Kigali	4.1 How have the recent innovative initiatives and best practices for sustainable urban public transport been implemented? 4.2 What are the barriers and limitations to achieving sustainable urban public transport in Kigali?	Use of Public transport	Usability	Economy	Documentary Analysis	Qualitative	businesses, agriculture, industry
				Frequency	Documentary analysis	Quantitative	The average number of trips per day, per week, per month, per year
				Population pressure	Documentary analysis	Qualitative	population growth rates, migration, fertility, mortality
				Mobility	Documentary analysis	Qualitative	Average and variation in travel time, travel costs
				Occupancy	Documentary analysis	quantitative	Number of passengers, Population using public transport, many public vehicles
				Infrastructure	Key informants	Qualitative	Road improvements, traffic management facilities (Bus Rapid Transit)
				Electrification	Key informants	Qualitative	Alternative fuel, Electric cars

3.5 Validity and Reliability

3.5.1 Validity

Research validity is the extent to which requirements of the scientific research methods have been followed during the process of generating research findings (Dudovskiy, 2019). Validity is considered a compulsory requirement for all types of study. There are different types of research validity, namely, construct validity, content validity, internal validity, and external validity. It is essential to address validity in the research because it measures the accuracy of results within a study and, therefore, the degree to which assumptions, correlation, and relationships can be made.

Construct validity is about the measurements of a variable in a study behave in the same way as the variable itself. Construct validity was addressed in the study by examining past research and looking at different aspects of some variables used in the study.

Content Validity is the extent to which a measure “covers” the construct of interest. Content validity was assessed by carefully checking the measurement method against the conceptual definition of the construct (Dudovskiy, 2019). Findings can be said to be internally invalid because they may have been affected by factors other than those thought to have caused them or because the researcher’s interpretation is not supportable (Selinger & Shohamy, 1989). The researcher used the allocated time for data collection and data analysis efficiently to avoid data misinterpretation. Findings can be said to be externally invalid because they cannot be extended or applied to contexts outside those in which the research took place (Selinger & Shohamy, 1989). External validity was addressed in this study by describing well population characteristics and using the right sample size.

3.5.2 Reliability

Research reliability refers to the extent to which the same results can be obtained using the same methods. In other words, research is said to be of high-security levels if other researchers can generate some results using the same methods under similar conditions (Dudovskiy, 2019). Reliability and validity are used interchangeably in research. There is a need to address safety because it is a significant factor in the assessment (Soto & John, 2007). Additionally, it is presented as an aspect contributing to validity and not opposed to validity, reliability is seen as the degree to which a test is free from measurement errors. Reliability was addressed in this study by comparing field data for Vehicle kilometers traveled with electronic data saved in Rwanda Regulatory Authority (RURA) (Rwanda Utility Regulation Authority, 2018). Additionally, pilot testing was carried out to ensure quality and control.

3.6 Research Ethics

The research sought permission from government institutions to assure security and honesty. A recommendation letter attached as annex 7, together with a note describing this study, was submitted to the Rwanda National Council Science and Technology, and a research permit was issued (See annex 6). IRB clearance assures the protection of the rights and welfare of human subjects. The approval means that the volunteers will participate in this research if they are willing to. There was no disclosure of any information provided in the study to third parties unless permission was granted. Information obtained from participants was not shared, and their names were kept confidential. There was no risk associated with the study because the researcher had a permit for carrying out the research. The participants were not paid or promised to get any grant of any kind. Therefore, the participants had the right to refuse or pull out from the interview if they were not willing to participate. The researcher kept the supervisor informed about the progress of the research. Plagiarism software was used to confirm the research project's originality, and to check if it was not copied from any other person’s work. A copy of the report shall be sent to the University of Botswana Library and School of Graduate Studies (SGS), Department of Environmental Science (DES), and other third parties on request. The study complied with the Data Protection act 1998. Information was kept private except where the participant willingly accepts or gives permission for their views and names to be published. Environmental ethics believes in the ethical relationship between human beings and the natural environment, including the rights of non-human animals in our ethical and moral values. Even if the human race is considered the primary concern of society, animals and plants are no way less important. The study gave fair share treatment for both human and non-human species. They had a right to get their fair share of existence.

3.7 Summary and Conclusion

This chapter gave detailed information on the three main research methods that were used in the study. The three research methods are a bottom-up approach (IPCC tier 1), Key informant, and Interview and Documentation analysis. These methods complement each other; data that provided qualitative data gave an analytical and logical interpretation of conclusions drawn from those proving quantitative data. Besides, reliability and validity were used interchangeably in the study. Furthermore, research ethics were followed to provide smooth data collection. The next chapter presents the estimated GHG emissions, transport policy, and mitigation options for public transport in Kigali. The chapter also discusses the findings of the study of other related literature.

CHAPTER 4:RESULTS AND DISCUSSION

Introduction

Chapter 3 described the methodology, and the instruments used to collect data for this study. In addition, the chapter demonstrated how the findings were analyzed and presented. For instance, how the data addressing specific research questions were collected and analyzed in line with the research objectives. This chapter presents the estimated greenhouse gas emissions, transport policy, and mitigation options for urban public transport in Kigali. Also, the chapter discusses the findings and other related literature. Furthermore, this chapter applies the conceptual framework to interpret the results.

4.1 Objective 1: Estimating GHG emissions of public transport in Kigali from 2012 to 2019

Overview

The data on numbers of public transport are taken from the Rwanda Utility Regulatory Authority (RURA) yearly report and the available data are from 2012 up to date (RURA, 2019). Before 2012 public transport was an informal sector (MININFRA, 2012). An informal transport sector means that public transport comprises small vehicles and low-performance services that were privately operated. Informal public transport usually charged commercial rates for the most part, and it was characterized by low-income cars with fewer individuals making non-work trips. Finding documentation from trusted sources on the number of public vehicles and fuel economy for a specific region like Kigali was nearly impossible (RURA, 2012). However, the researcher used reports from public vehicle companies and compared them with data available in government institutions such as RTDA and RURA.

Table 4.1 below shows the level of urban public transportation in Kigali city as of 2019. Public transport in Kigali is divided into three types of vehicles used in public transport: motorcycles, taxicabs, and buses. Both motorcycles and taxicabs consume gasoline energy, whereas buses consume Diesel energy.

Table 4. 1 Types and categories of public transport vehicles and fuel in Kigali

Sector	Sub-sector	End-use vehicles	Consumed energy
-Passenger Transport	-Public transport	-Motorcycle -Taxicabs -Buses	-Gasoline -Gasoline -Diesel

Source: Author’s field data (2020)

4.1.1 Vehicles population and their manufacturing year

As discussed in Chapter 1 Kigali public transport is made of 3 different modes of transport, namely buses, motorcycles, and taxicabs. A taxicab is an automobile that carries passengers for a fare usually determined by the distance traveled. The number of taxicabs increased throughout the years due to the increase in the Kigali population. As discussed in chapter two, the fourth Rwanda population census of 2012 indicated that the total population increased from 8,128,553 people in 2002 to 10,515,973 people in 2012 (Rwanda Environmental Management Authority, 2018). Kigali had 243 Taxicabs in 2012 and 816 taxicabs in 2019 distributed unequally in the three districts of Kigali city (Gasabo, Nyarugenge, and Kicukiro district) as described in figure 4.1. The number of motorcycles increased throughout the years and it is projected to keep increasing. According to the World Bank report, motor vehicles (per 1,000 people) in Rwanda were reported at 4.7 in 2010, and it was projected to be 5.2 in 2021 (World Bank, 2021). Additionally, with almost 216,204 registered vehicles in Kigali, nearly 52% are motorcycles and almost half of this percentage operate in Kigali city. Kigali city had almost 52 motorcycle cooperatives as described in chapter 3, and members of those cooperatives could own one or more motorcycles.

Kigali had 9450 motorcycles in 2012 and 17082 motorcycles in 2019 distributed unequally in the three districts of Kigali city (Gasabo, Nyarugenge, and Kicukiro district). Table 4.2 below shows the trends in the number of taxicabs, motorcycles, and buses from 2012 to 2019. The number of vehicles increased every year. Especially in the year 2017 showed a considerable increase in buses and a regular increase in other vehicle categories. In 2018, the number of buses reduced because the small buses were replaced by the big buses. Public transport generation 1 which started in 2012, forced the bus operators to replace small buses with big buses. In addition, there was a tax waiver policy on imported passenger transport vehicles, which aimed at increasing bus operators purchasing power and reduce transport costs (MININFRA, 2012). This decrease in the number of small buses resulted in a decrease in the total number of buses.

Table 4. 2 Public transport vehicle number trends in Kigali 2012-2019

Year	Taxicabs	Motorcycles	Buses
2012	243	9450	113
2013	320	10450	143
2014	396	11450	406
2015	562	12450	433
2016	728	13546	535
2017	814	14537	609
2018	899	15527	481
2019	816	17082	449

Source: (RURA, 2020)

Buses are divided into categories: One category is made of small buses known as Coaster with a capacity number of 29 passengers and another category is made of big buses with a capacity number of 70 passengers. These buses are distributed unequally in the three districts of Kigali city (Gasabo, Nyarugenge, and Kicukiro district) and three bus companies' operators (KBS, Royal, and RFTC).

The manufacturing year of taxicabs, buses, and motorcycles were between the years 1991 to 2018. Motorcycles were manufactured between the years 2005 to 2019. The survey made in 2019 in Kigali city by the researcher shows that the majority of the motorcycles that were operating in Kigali city were between two to three years old. It is assumed that most motorcycles beyond three years old are sold in urban areas. The manufacturing year of taxicabs ranged from 1991 to 2002 in the taxicabs industry. However, the majority number was manufactured in the year 2002.

Eighty percent of buses were manufactured between the years 2005 to 2018. However, the majority of big buses were manufactured in recent years between 2017 and 2019. A study by the Rwanda Ministry of Environment in 2018 called for enforcement of vehicle emissions inspection to reduce pollution and GHG emissions from vehicles. It also highlighted that the average age of cars in Rwanda was at that time 19 years, with more than half of the cars made before 1999. Ninety-five percent of vehicles were more than ten years old, which explains why they are the primary pollutants and emitters (REMA, 2018c).

4.1.2 Fuel economy and fuel consumption

Vehicle fuel economy and consumption are often used interchangeably in the literature(Mbandi, et al., 2019). In this study, fuel economy refers to the volume of fuel consumed per distance (L/100km), and fuel consumption refers to the volume of fuel consumed per kilometer (L/km). Three variables were used: i) average days per week, a vehicle travels (days/week), ii) average distance vehicle travels per day (km/day) and iii); average fuel per vehicle per day (L/day) (see annex 1 and 2). These linear variables were used to determine fuel consumption (FC) and mileage (VKT), which was, in turn, used to calculate fuel economy, denoted as FE'. FC (L/day).

Fuel consumption per day (L/day):

FC= TFM/COF/NOD

FC: Fuel Consumption (L/day)

TFM: Total money spend on fuel per month (Rwfs/month)

COF: Cost of fuel (Rwfs/L)

NOD: Number of days per month (day/month)

Fuel economy (L/100 km):

FE'= (FC/VKT) x100

FE': Calculated fuel economy (FE') (L/100km)

FC: Fuel Consumption (L/day)

VKT: Vehicle Kilometer Travelled (VKT) (km/day)

Source: (Mbandi, et al., 2019)

A case study based on an urban transport survey in Nairobi, Kenya, presented a methodology for estimating fuel economy in such cities(Mbandi, et al., 2019). The case study acknowledged that the lack of data on public transport was a major challenge in most African cities, a case for Nairobi and Kigali. The methodology for estimating fuel economy was developed to estimate fuel in such cities. That methodology was also used in this study, given that Rwanda is in the same region as Kenya and has similarities in its public transport sector. For instance, Nairobi public transport comprises taxis, Matatus/minibusses/buses, and motorcycles similar to Kigali public transport vehicles (Kiiru, 2015).

To estimate the fuel quantities, data entered in the IPCC inventory software were based on the Vehicle Kilometer Travelled (VKT) and volume of fuel consumed per distance (L/100km). Data collected showed that the fuel consumed per distance by public vehicles in Kigali city differed depending on kilometers traveled per year, car characteristics, maintenance, and year of manufacturer. For instance, the car tax ranged from 8 to 12 liters per 100 km, motorcycles ranged from 12 to 15 liters per 100 km, and the buses ranged from 17.9 to 29.5 liters per 100km.

As described in Table 4.3 below, the yearly average fuel economy for one taxicab in Kigali varied between 1,449.60 liters to 3139.2 liters of gasoline. Also, the yearly average fuel economy for one motorcycle varied between 1466.7 liters to 1789.3 liters of gasoline, as shown in Table 4. 3. Additionally, the yearly average fuel economy for one big bus with 70 passenger capacity varied between 20160 liters to 30556.4 liters of diesel, as shown in Table 4.3. Whereas, the yearly average fuel economy of one small bus with 29 passenger capacity varied between 17295.6 liters to 20160 liters of diesel.

Table 4. 3 Annual vehicle average fuel consumption per manufacturing year in Kigali

Year of Manufacturing	Average fuel (Liters) Taxicabs	Average fuel (Liters) Motorcycles	Average fuel (Liters) Bus (70 passengers)	Average fuel (Liters) Bus (29 passengers)
1991	3,139.20	-	-	-
1993	1,911.27	-	-	-
1994	1,608.00	-	-	-
1995	1,449.60	-	-	-
1996	1,622.40	-	-	-
1997	2,243.66	-	-	-
1998	1,838.40	-	-	-
1999	1,641.60	-	-	-
2000	1,751.04	-	-	-
2002	2,880.00	-	-	-
2005	-	-	30,556.40	17,295.60
2011	-	1,680.00	20,160.00	20,160.00
2012	-	1,466.70	20,160.00	-
2013	-	1,560.00	20,160.00	20,160.00

2014	-	1,760.00	27,888.00	-
2015	-	1,546.70	-	-
2016	-	1,732.30	-	-
2017	-	1,789.30	27,888.00	-
2018	-	1,752.80	27,88 8.00	-
2019	-	1,609.10		-

Source: Author's field data (2020)

Total fuel for all vehicle categories was calculated based on the yearly average fuel times the total number of vehicles. The following formula (1) as stated in chapter 3 was used to estimate the total fuel.

$$Estimated\ fuel = \sum_{i,j,t}[Vehicles_{i,j,t}.Distance_{i,j,t}.Consumption_{i,j,t}] \qquad (1)$$

Where:

Estimated Fuel =total estimated fuel use estimated from a distance traveled (VKT) data (l)

Vehicles i, j, t = number of vehicles of type i and using fuel j on road type t

Distance i, j, t = annual kilometers traveled per vehicle of type i and using fuel j on road type t (km)

Consumption, j, t = average fuel consumption (l/km) by vehicles of type i and using fuel j on road type t

i = vehicle type (e.g., car, bus)

j = fuel type (e.g. motor gasoline, diesel, natural gas, LPG)

t = type of road (e.g., urban, rural)

While estimating fuel consumption for Kigali public transport vehicles the trips that take place entirely in the city were analyzed to estimate the urban public fuel consumption. Buses in Kigali city operate only in three specified network routes (Main road). Taxicabs and motorcycles also have access to those routes most of their trips, and they also use other minor roads and rural roads sometimes. Hence, it was difficult to isolate the estimated fuel consumption that could have been used in rural and on the other road type for motorcycles and taxicabs. However, according to the IPCC report (2006), the bottom-up approach used in this study reduces the cross-boundary and road type uncertainty.

Table 4. 4 estimated total fuel consumption for all public vehicles in Kigali from 2012 to 2019

YEAR	TAXICABS	FUEL TYPE	MOTO	FUEL TYPE	BUS	FUEL TYPE
2012	589,838.89	GASOLINE	15,908,646.00	GASOLINE	2,682,594.60	DIESEL
2013	784,378.07	GASOLINE	17,592,525.00	GASOLINE	3,398,888.92	DIESEL
2014	969,878.74	GASOLINE	19,276,404.00	GASOLINE	9,781,279.76	DIESEL
2015	1,383,145.99	GASOLINE	20,960,283.00	GASOLINE	10,308,499.04	DIESEL
2016	1,793,533.25	GASOLINE	22,802,469.60	GASOLINE	12,737,129.44	DIESEL
2017	2,006,246.18	GASOLINE	24,370,860.00	GASOLINE	14,350,955.08	DIESEL
2018	2,214,804.17	GASOLINE	26,149,593.07	GASOLINE	11,447,277.52	DIESEL
2019	2,009,126.18	GASOLINE	28,756,081.70	GASOLINE	10,659,994.24	DIESEL

Source: Author's field data (2020)

The calculated total fuel per vehicle category was converted into Gigagrams (Gg) using the following density: Gasoline (0.74 kg/Liter), diesel (0.84 kg/liter). The trends of yearly total fuel consumption per vehicle category are shown in Figure 4.1 below. The findings indicate that the number of motorcycles is approximately 22 times higher than the number of taxicabs and 33 times higher than buses. Also, the results show that the total fuel consumption of motorcycles is higher compared to other vehicle categories. A report by Bajpai (2014) about the role of the government in sustainable mobility and accessibility in Rwanda indicated that with the increased population, many new developments come along with a sharp rise in motorization in Kigali city. Additionally, the increased concentration of economic activities, and the arrival of new migrant populations, and increased personal vehicles, especially cars and motorcycles resulted in heavy congestion (Bajpai, 2014). Buses and taxicabs were not reliable because of the time spent in traffic, waiting time at Bus Park, and lack of Bus Information System (BIS) at the bus station; hence many people preferred motorcycles over other modes of public transport (Nkurunziza, 2018a). On this note, motorcycles tend to cover a long distance and most of the time on speed. Therefore, motorcycles' fuel consumption is higher compared to other modes of public transport.

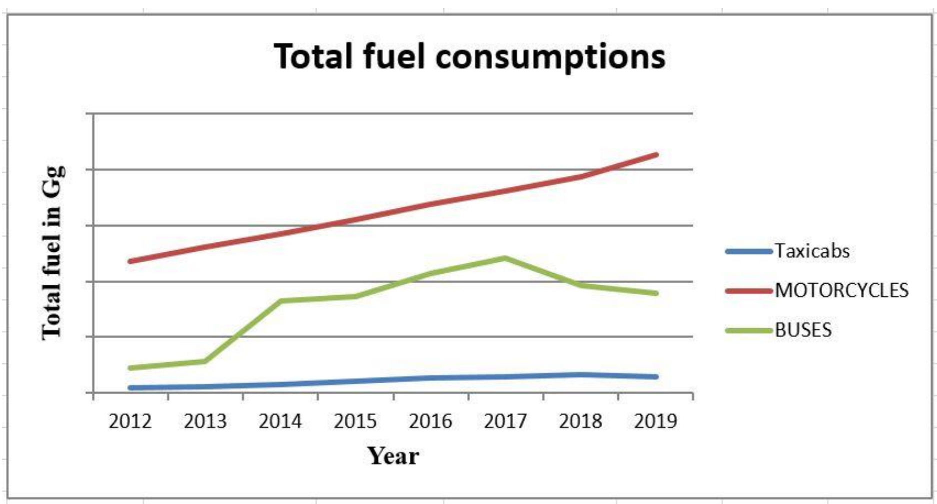

Figure 4. 1 Total fuel consumption for all Kigali public vehicles from 2012 to 2019

Source: Author's field data (2020)

4.1.3 GHG emissions for public transport in Kigali city

Liquid fuel

There are different types of fuel, such as solid fuel, gas, liquid fuel, and other fuels. The study considered liquid fuel because Kigali public vehicles consume only liquid fuel. The inventory considered liquid fuels for gasoline (138.80 Gg) and diesel (63.31Gg) as energy fuels that contributed to total GHG emissions. Figure 4.2 below shows the activity of liquid fuel in the terajoule. The activity of liquid fuel is the total liquid fuel that has been used by vehicles (Motorcycles, taxicabs, and buses) each year from 2012 to 2019. There has been an increase in the total liquid fuel used by all vehicles. The total liquid fuel ranged from 637.653 Tj from 2012 to 1393.561 Tj from 2019, as shown in Figure 4.2.

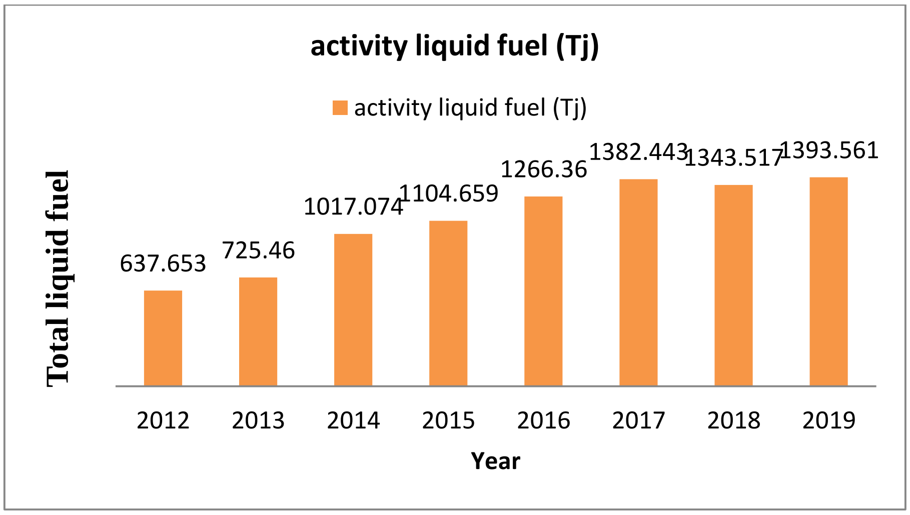

Figure 4. 2 Activity liquid fuels for all public transport vehicles in Kigali 2012-2019

Source: Author's field data (2020)

Total GHG emissions from all vehicles and per vehicle category

According to the IPCC guidelines 2006, the following are the greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3), trifluoromethyl sulfur pentafluoride (SF_5CF_3), and halogenated ethers (IPCC, 2006). However, this study focused on the three major greenhouse gases, namely carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), due to the scope of the study. Mobile sources produce direct greenhouse gas emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from the combustion of various fuel types (IPCC, 2006). This study covered direct greenhouse gas emissions from road transport under three categories, car category (Passenger cars with 3-way catalysts), bus category (heavy-duty trucks and buses), and motorcycles category. Collected data on yearly total fuel consumption was entered into the IPCC inventory software, and total GHG emissions and emissions per gas ($C0_2$, CH_4, and N_20) were generated automatically.

The total GHG emissions from public transport shown in Figure 4.3 were as follows: 45.26 Gg in $C0_2$ equivalent in 2012; 51.50 Gg in $C0_2$ equivalent in 2013; 72.20 Gg in $C0_2$ equivalent in 2014, 78.41 Gg in $C0_2$ equivalent in 2015; 89.89 Gg in $C0_2$ equivalent in 2016; 98.13 Gg in $C0_2$ equivalent in 2017; 95.37 Gg in $C0_2$ equivalent in 2018; and 98.92 Gg in $C0_2$ equivalent in 2019. The results in Figure 4.3 show that there has been a relative increase in GHG emissions of public transport in Kigali from 2012 to 2019. However, the year 2019 showed slightly higher emissions the increase was likely caused by the increased number of vehicles. The year 2019 was followed by the year 2017, where the number of buses was higher as well before they replaced small buses with bigger buses. This increase in the number of vehicles in 2017, could be the explanation to why 2018 emissions were lower than that of 2017.

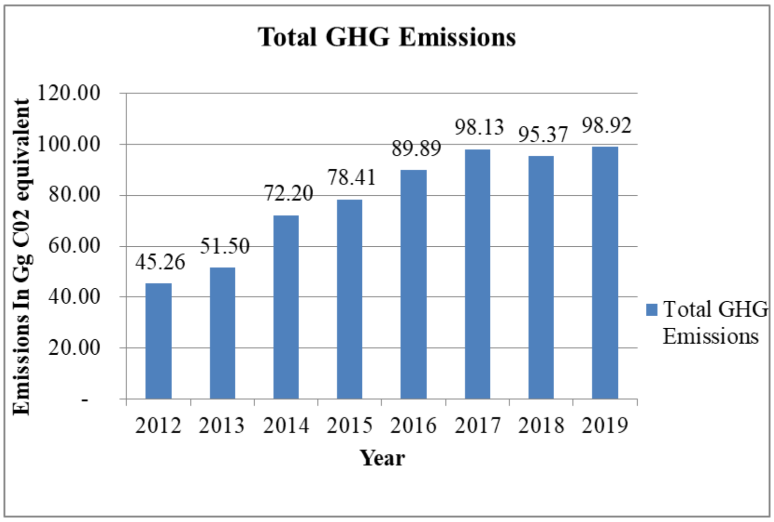

Figure 4. 3 Total annual GHG emissions from all public transport vehicles in Kigali 2012-2019

Source: Author's field data (2020)

Emissions per vehicle category, as described in Figure 4.4, showed the contributions of each category to the total GHG emissions. The GHG emissions from taxicabs ranged from 1.38 Gg in CO_2 equivalent in 2012 to 4.69 Gg in CO_2 equivalent in 2019.

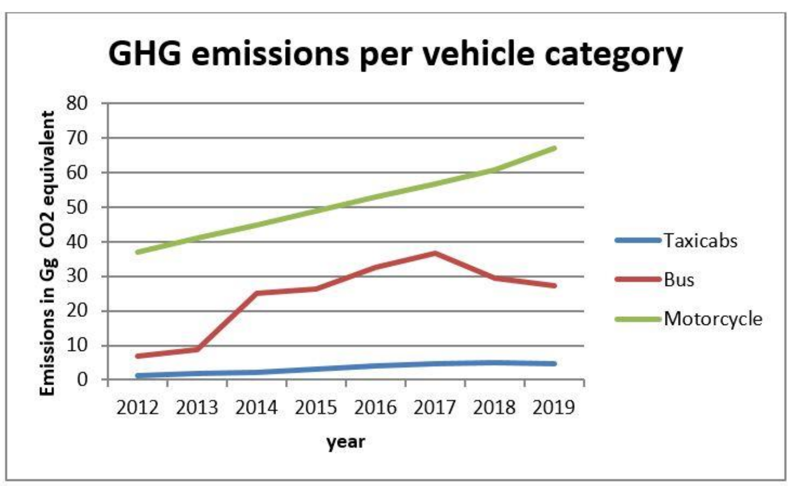

Figure 4. 4 GHG Emissions per vehicle category in Gg CO_2 equivalent in Kigali 2012-2019

Source: Author's field data (2020)

The year 2018 marked slightly higher emissions of 5.16 Gig in $C0_2$ equivalent the increase was likely caused by the increase in the number of vehicles, which reduced in the year 2019. The GHG emissions from buses ranged from 6.87 Gg in CO_2 equivalent in 2012 to 27.32 Gg in CO_2 equivalent in 2019. However, the year 2017 ranked the highest emissions, most likely because of the increase in the number of vehicles, which was reduced in the year 2019. Furthermore, GHG emissions from motorcycles increased proportionally, this was likely caused by the increase in the number of motorcycles each year. Motorcycle emissions ranged from 37.01 Gg in $C0_2$ equivalent in 2012 to 66.92 Gg in $C0_2$ equivalent in 2019. Note that other factors could contribute to the increase in GHG emissions from the transport sector in addition to vehicles number such as vehicle age, driver behaviors, type of engine, engine capacity, kilometer traveled, vehicle model, etc.…

Motorcycles emitted more GHG emissions compared to other public transport modes (Vehicle categories) followed by buses from 2012 to 2019 in Kigali. According to the 2013 Ministry of Infrastructure (MININFRA) report, out of 118,656 vehicles registered in Rwanda, 48.86% were motorcycles. There were a large number of motorcycles in Kigali compared to other public transport vehicles. The emissions from motorcycles were found to be the dominant contributor to the total GHG emissions from the transport sector (MININFRA, 2013).

Table 4.5 shows the total number of cumulative registered vehicles in Rwanda from 2012 to 2018 according to the Rwanda Revenue Authority (RRA). In 2012 the percentage of the taxicabs, motorcycles, and buses in Kigali public transport was 0.1%, 4.3%, 0.05% consecutively from the total cumulative number of vehicles registered in Rwanda. Additionally, in 2018 the percentage of taxicabs, motorcycles, and buses in Kigali public transport was 0.4%, 7.1%, 0.2% consecutively from the total number of cumulative registered vehicles in Rwanda.

Table 4. 5 Total number of cumulative registered vehicles in Rwanda 2012-2018

Source: National Institute of Statistics of Rwanda (2018)

Category	Cumulative up to 31-12-2012	Cumulative up to 31-12-2013	Cumulative up to 31-12-2014	Cumulative up to 31-12-2015	Cumulative up to 31-12-2016	Cumulative up to 31-12-2017	Cumulative up to 31-12-2018
Caterpillar	3	25	75	105	126	142	145
Bus	489	549	769	1059	1264	1464	1576
Trucks	3378	3738	4070	4961	6049	6881	7694
Pick –up	14472	15163	15734	16402	17245	17953	18618
Special engine	638	733	832	1187	1726	2256	2856
Jeeps	15828	17361	18583	20276	22292	24419	26715
Microbus	147	151	153	254	545	1016	1466
Minibus	5528	5827	6058	6160	6283	6343	6411
Cars	22699	24834	26850	30238	33080	35062	36951
Motors	60980	67382	74774	85072	93866	101694	112404
Trailers	750	812	851	887	960	934	976
Semi-trailers	186	186	194	218	232	278	316
Tricycle	61	63	68	73	73	73	73
Unknown	0	0	1	1	2	3	3
Forklift	0	0	0	0	0	0	0
Total	**125159**	**136824**	**149012**	**166893**	**183743**	**198518**	**216204**

The general trends shown in Figure 4.5 were consistent in carbon dioxide and showed a significant change since 2017. This trend relates to the increased number of vehicles in that particular year.

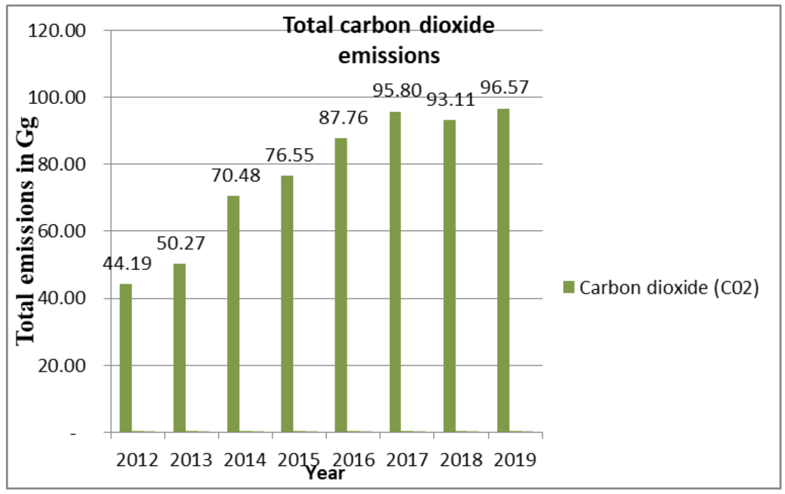

Figure 4. 5 Total emissions of carbon dioxide for Kigali 2012-2019

Source: Author's field data (2020)

Total emissions of carbon dioxide in Figure 4.5 show the trends of carbon dioxide ($C0_2$) which ranged from 44.19 Gg in 2012 to 96.57 Gg in 2019. Other gases such as Methane gas (CH_4) ranged from 0.02 Gg in 2012 to 0.05 Gg in 2019, whereas N_2O ranged from 0.00204 Gg in 2012 to 0.00445 Gg in 2019. Carbon dioxide had a more significant percentage as compared to other gases; that's why other gases are not shown in the figure.

Pearson Correlation Analysis to estimate the relationship between Kigali public transport vehicles and GHG emissions

Pearson Correlation Analysis was used to estimate the relationship between total Kigali public transport vehicles and total GHG emissions. Data for Kigali public transport vehicles and GHG emissions for a period of 8 years (2012 to 2019) were entered in SPSS (Statistical Package for the Social Sciences) and the results are shown in Table 4.6. Generally, the Correlation coefficient (r) or Pearson correlation ranges between -1 (perfect strong negative relationship), and + 1 (perfect strong positive relationship). The results in Table 4.6 below show that r is 0.955, hence, there is a strong positive relationship between the increasing number of public vehicles and GHG emissions. Specifically, if the number of vehicles increases, GHG emissions will increase too.

Table 4. 6 Correlation analysis between total GHG emissions and total public transport vehicles

		Total GHG Emissions	Total Kigali public transport vehicles
Total GHG Emissions	Pearson Correlation	1	.955**
	Sig. (2-tailed)		.000
	N	8	8
Total Kigali public transport vehicles	Pearson Correlation	.955**	1
	Sig. (2-tailed)	.000	
	N	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Author's field data (2020)

Figure 4.6 below shows GHG emissions of Kigali public transport over time. It clearly shows how the emissions increased from the year 2012 to 2019. Additionally, the number of Kigali Public transport vehicles increased overtime during that period as shown in Figure 4.7. Therefore, the findings showed there was an increase in the total number of Kigali public and GHG emissions over time as shown in Figure 4.8. Hence there is a strong relationship between GHG emissions and the total number of vehicles.

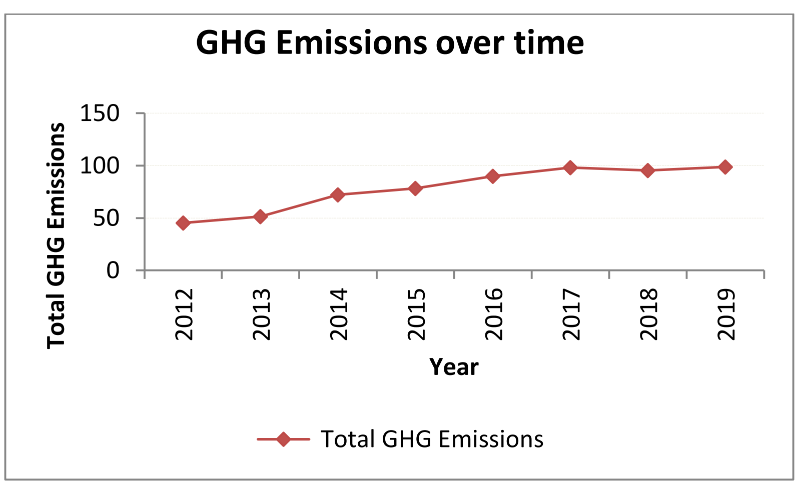

Figure 4. 6 GHG emissions of Kigali public transport over time

Source: Author's field data (2020)

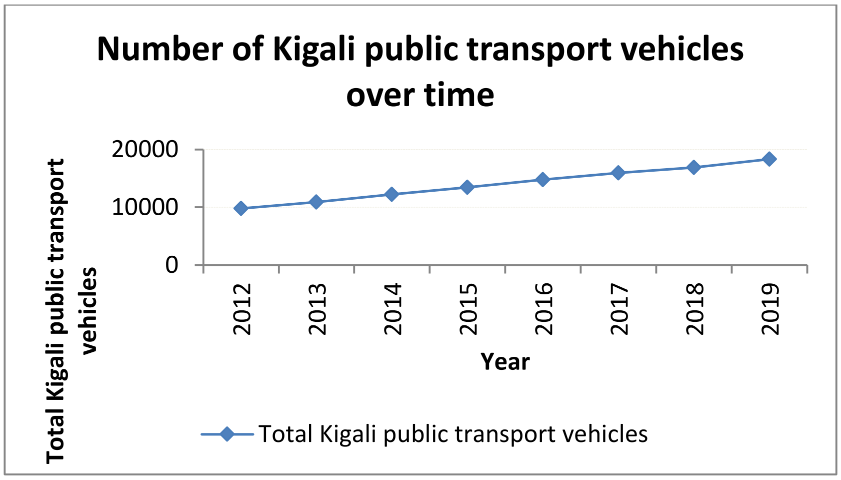

Figure 4. 7 Number of Kigali Public transport vehicles over time

Source: Author's field data (2020)

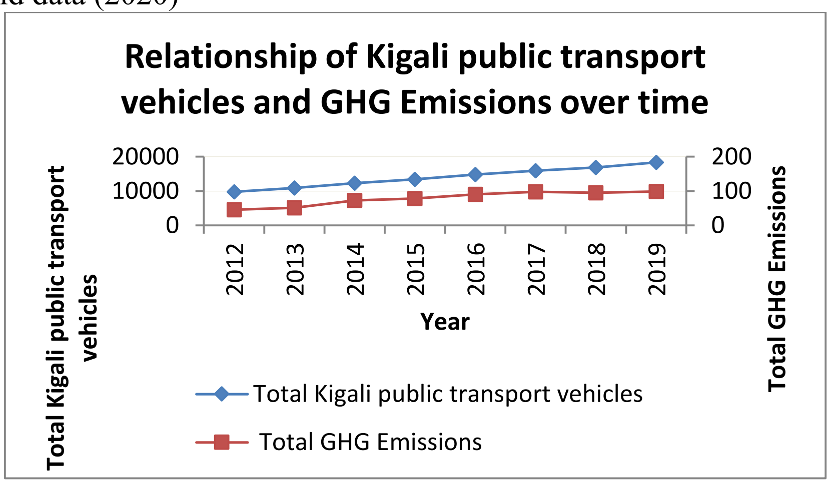

Figure 4. 8 Relationship of Kigali public transport vehicles and GHG emissions over time

Source: Author's field data (2020)

Comparison of results of studies estimating GHG emissions in Rwanda

According to the first, second and, third Rwanda national communication to the UNFCCC, the baseline trends of GHG emissions from the historical emissions from 1990 to 2015; the baseline years 2002, 2005, and 2012 were chosen. For the year 2002, the energy sector dominated $C0_2$ emissions by 92%, followed by land use and forestry with CO_2 emissions of 7%. In 2002, Carbon dioxide ($C0_2$) emissions from the transport sector were 259.68 Gg and 0.04173 Gg of CH_4 (REMA, 2005).

The results of the public transport sector in this study showed that in 2012 total emissions were 45.26 Gg CO_2 equivalent. Whereas, the overall results of transport sector emissions as a whole based on the baseline year of 2012 were 458.29 Gg of CO_2equivalents (REMA, 2018b). The overall GHG emissions results accounted for all transport categories, including private, public, and goods vehicles in Rwanda. Additionally, in 2012 $C0_2$emissions from the transport sector were dominant, followed by CH_4 and N_2O, 54.85%, 37.12%, and 8.03%, respectively (REMA, 2018c). Hereafter, when comparing the overall GHG emissions of 45.26 Gg $C0_2$ equivalents from this study to the overall GHG emissions of 458.29 Gg of CO2 in the same year (2012). It is noted that public transport in Kigali accounted for nearly 9% of total GHG emissions from all vehicles in Rwanda.

The IPCC methodology applied in this study to estimate the GHG emissions was also used in the other studies. For instance, a report about Rwanda's national communication to the UNFCCC, done by REMA, used IPCC inventory software to produce reports showing GHG emissions in all sectors (REMA, 2018c). However, the report produced overall emissions based on fuel allocations. In contrast, this study focused on Kigali city and considered fuel economy to estimate the emissions. Limited studies were carried out to estimate the emissions in Kigali by sediment by the Rwanda Environment Management Authority (REMA), as discussed in chapter 2.

A study by Sudmant (2017) discussed in chapter 2 of this study, measured transport emissions in Kigali. This study developed a structured approach to analyzing the economic case and the impact on emissions of implementing low carbon urban measures in the city. The period 2000-2015 saw rapid increases in transport, energy use (9.0% per annum), energy expenditure (19.7% per annum), and greenhouse gas emissions (8.9% per annum) in Kigali. This increase means that transport 'emissions increased faster compared to other sectors in the city, followed by the building sector (8.1%) and the waste sector (6.4%) (Sudmant, Colenbrander, Gouldson, & Chilundika, 2017). This study also showed a steady increase in emissions from public transport from 2012 to 2019. Another study by Ison and Ryley in 2007 estimated the emissions from public transport, including the Rail sector in the United Kingdom (UK). The study used IPCC software and its proposed policy options for minimizing GHG emissions in the United Kingdom. This study did not use the estimated fuel based on the kilometer traveled. The emissions were estimated based on energy consumption allocation.

4.2 Identification of GHG emissions reduction policy options for public transport in Kigali

The interviews were conducted using an interview guide of twenty-three questions using a semi-structured interview (See annex 4). The study used both cluster sampling and purposeful sampling. Interview questions were guided by the relevant literature and the research questions. All the five interviewees were given a choice to remain anonymous; however, their institutions were identified and their role in public transport as described in Table 4.6.

Table 4. 7 Interviewee's organizations and their role in public transportation

Interviewees	Organization type	Name of The organization	Role of the organization in public transportation	Interview technique
A	Public	RURA (Rwanda Utility Regulation Authority)	The authority regulates inland waterway transportation of persons and goods using vessels and regulates driving school services and freight forwarders services**.**	Personal
B	Public	CoK (City of Kigali)	Building and Sustaining a City of Character, Vibrant Economy and Diversity through Strong Partnership	Personal

			with Stakeholders to Provide Responsive, Rapid and Effective urban development including that of public transportation	
C	Public	REMA (Rwanda Environmental Management Authority)	Mainstreaming, public education and compliance monitoring of Climate Change Concerns in Rwanda's Transport Sub-sector	Personal
D	Public	MININFRA (Ministry of Infrastructure)	To provide modern infrastructures for sustainable economic growth and socio-economic development and policy, including that of public transportation	Personal
E	Public	RTDA (Rwanda Transport Development Agency)	To gain modern infrastructure, cost-effective, and quality services while ensuring sustainable economic growth and developing an eco-friendly, safe, and seamless, integrated multimodal transport system for passengers and goods at the national and regional levels.	Personal

Source: Author's field data (2020)

By interviewing different people with different roles in different organizations on the same topic, the researcher arrived at a broader understanding of an activity (e.g., alternative fuel, emissions reduction options, challenges, transport policy, etc.). Usually, only one person from each organization had a decisive role and was part of decision-making in the public transportation sector. Hence the strategic choice of using only five interviewees provided enough data to answer the research interview questions. Secondary data on published institutions' materials and institutions' reports were also considered for validating interview answers.

The content analysis was used to analyze three variables: policy, sustainable public transport, and climate change mitigation. The analysis involved coding categories that are derived directly from the text data. The major themes from the interviews were compared with those of the institute reports. Several major themes were identified: Emission reductions options, Policy options, Use of alternative fuel, Transport policy Mode of transport and GHG emissions, Transport preferences, Public transport safety and crime, Maximum walking distance, Information, Accessibility, Availability, Barriers, and limitations of using public transport, Comfort using public transport, number of transfer, time spent in travel, Road network, and infrastructure.

4.2.1 Objective 2: To identify GHG emissions reduction options for public transport in Kigali

The section focuses on objective 2,

Emission reduction options

Ninety percent (4 out of 5) of the interviewees emphasized the use of electric vehicles to reduce emissions in public transport. However, the use of electric vehicles required massive investments. The respondents believed that with the help of external funding, it could be achieved. Besides, Rwanda has enough electrical capacity to support electric vehicles, reported by one of the respondents. The interviewees also shared that revisiting the quality of fuel used in Rwanda can also reduce public transport emissions. Additionally, the shift towards mass transportation could bring a significant change in public transport. The interviewees mentioned that introducing much bigger buses to replace the medium buses that operate in Kigali could reduce emissions in the public sector. It was noted by interviewees that the bigger buses can help solve the problem of traffic jams and long queues at the bus station. Also, introducing bigger buses can increase the number of passengers that use public transport means.

Several interviewees (4 out of 5) highlighted different options that Kigali city transport could adapt to reduce GHG emissions, such as introducing BRT. BRT would contribute towards reducing emissions, and it can reduce bus traffic. A respondent said, "BRT encourages people to shift from private vehicles to public vehicles due to its reliability." The respondent also mentioned that the use of electric vehicles is another option that could be used. Another respondent confirmed that there was a feasibility study that showed that Rwanda had enough electricity to support the initiative of using electric vehicles in public transport.

Applying the urban ecosystem conceptual framework discussed in chapter 2 of this study helped analyze the causes of emissions, consequences, and how they can be addressed. The framework contributed to how urban sustainability could be created (Dakhia & Berezowska, 2016). The framework showed the cause of emissions being the increase in public transport use, hence the increase in fossil fuel use. Transport and the use of fossil fuels lead to emissions that cause global warming and climate change. The conceptual framework identified how emissions from public transport could be addressed in Figure 2.1 under chapter 2 of this study. The framework identified the following mitigation options to address climate change: energy-efficient vehicles, walking, cycling, bus rapid transit, bus information system, and vehicle Information Technology System (ITS, Electrification). It also suggested the following policy options: subsidies for low carbon-intensive vehicle emissions standards and regulation.

Bus Rapid Transit (BRT) constructions make public transport efficient, affordable, and durable (Hughes & Xianyuan, 2012). Before the 1960s, Curitiba, a city in Brazil, has been just like any other in terms of sustainability. In 1968 when the master plan for Curitiba was implemented, the country introduced BRT. Curitiba is currently considered as the most sustainable city in Brazil in terms of urban public transportation. This change has increased passenger numbers, for instance, 28% of trips are using this type of public transport with only 4.2 traffic fatalities per 100,000 people (compared to a 9.6 average in the region) (Rojas, 2018). The introduction of BRT has driven congestion down by 25% and 30% fuel consumption. Additionally, to avoid congestion in central areas, various streets in the Curitiba city center were pedestrianized.

Introducing BRT in Kigali could bring a significant change in fuel consumption, congestion, and an increasing number of passengers using public transport. However, these initiatives should not be implemented at this stage due to the way Kigali operates; it needs mass transportation first and other initiatives before we invest in BRT. A study carried out by UNEP Rwanda in 2013 stated that BRT was among the options to reduce emissions in the transport sector. However, the potential in Kigali with about 1 million inhabitants was limited, even if the congestion problems were growing. Hence, they concluded that the transport sector was generally not a source for potential emissions reduction (UNEP, 2013). Looking at the results produced by the Rwanda Environmental Management Authority (REMA) during national communications, and the results produced by this study, it is noted that there is an increase in transport sector emissions every year.

Use of alternative fuel

Most of the interviewees (3 out of 5)said there was no alternative fuel used in public transport. However, biofuels have been tested, but the cost of production was huge, and the project failed. It is noted that biofuels are a 'drop-in solution' to low-carbon transportation. Hence it requires the combustion of pure biofuels or as an additive in conventional fuel (Carey & Hogarth, 2011). It can be achieved in modified engines. There are several challenges with biofuels, including food and land security, their production stages, and technical issues. All biofuels should be low-carbon; therefore their sustainable credentials rely on the production cycle. The use of alternative fuel is a way to reduce emissions in the transport sector; it could be achieved by using renewable energy such as biofuels or electric vehicles.

Countries like Costa Rica (Earth Summit, 2002) embraced technological solutions and alternative fuels, including intelligent transport systems (ITS) and biofuels. Costa Rica reduced 40% of their emission from public transport and recently introduced electric cars to cut off more their emission (Irfan, 2018). Costa Rica implemented a much more conservative incentive-driven plan to get the rest of the way to zero net emissions. Technology in transport has also been proven to help in reducing general environmental problems such as noise and air pollution, oil dependency, and traffic congestion (Pojani & Dominic, 2015).

4.2.2 Objective 3: Public transport policy options contributing to GHG emissions reduction, Kigali

The section focuses on objective 3,

Transport policy

All the respondents mentioned that few policies that are restricted to environmental protection in public transport are available to the regulator for enforcement. There is a policy limiting the importation of old or used cars in Rwanda. Also, there is an additional vehicle tax as a fine for old or used cars. This policy is applied in public transport; however, the operators are given subsidies to import brand new vehicles.

The government of Rwanda formulated regulations on the quality of imported vehicles taking into account the year of manufacture, the mileage, and other technical characteristics required. Additionally, regulations on direct vehicle GHG emissions measurements and promoting public transports were formulated (REMA, 2006). Furthermore, maintenance and servicing vehicles are other policy instruments that have been in place to help reduce emissions.

The key informants reported a policy of using electric vehicles in public transport, at the pilot phase. The implementation of this policy started with motorcycles where they are trying to replace fuel-based motorcycles with electric motorcycles. One respondent said, "… *There are companies in Rwanda companies that are piloting this project in Kigali using chargeable batteries*…" A 2012 policy on public transport aimed at developing a sustainable public transport system, the preliminary public transport policies, and approach to public transport planning. One of the respondents said that the Ministry of Infrastructure (MININFRA) is developing a new policy to replace the 2012 policy to promote public transport. Most interviewees reported that the level of implementation of the 2012 policy was nearly 100% due to the achievement observed in public transport for the past years since 2012.

In 2012, the Government of Rwanda approved Public Transport Policy and Strategy, which directed the technical committee to assess the existing public transport problems. A report outlining the potential policy remedial measures on a short, medium, and long-term basis was submitted to the Ministry of Infrastructure (MININFRA, 2012). The governments of Rwanda, therefore, come up with a 2012 public transport policy and strategy for Rwanda, the policy focused on how on the following principles:

- Ensure universal public transport services for all citizens;
- Ensure accessibility (easy to use)
- Ensure mobility (door to door);
- Ensure availability for use (responsive to demand)
- Ensure reliability to use (providing services as per standard schedule or available on-demand); Promote Safety and security
- Ensure Monitoring & Evaluation of Level of service and performance; and, satisfied from the user's point of view (MININFRA, 2012).

The reforms inspired various investors to make capital investments into the passenger transport business level. The implementation of this policy reached nearly 100%, which led the ministry of infrastructure to develop a new public transport policy.

In 2012, the government of Rwanda approved the reforms within the public transport domain. There has been an introduction of a tax waiver policy on imported passenger transport vehicles, which aimed to increase bus operators' purchasing power and reduce transport costs (MININFRA, 2012). It was done in line with air pollution control policy and traffic congestion and accident control policy. These policies helped in phasing out the aged 18 passengers- minibus in Kigali.

Rwanda has a law No 18/2016 of 18/05/2016 governing the preservation of air quality and the prevention of air pollution in Rwanda (Duhuze, 2018). Article 9 of this law highlighted the means of transport operating in Rwanda to undergo an inspection for emissions control. It was mandatory for all vehicles operating in Rwanda except motorcycles to do an inspection (twice a year for all commercial and public transport vehicles and once a year for other vehicles) (Duhuze, 2018). The law helped control emissions from the transport sector.

Developing many policies that are in line with emissions reduction under public transport could cut public transport emissions. However, the implementation of transport policies in developing countries faces several challenges, such as funding for transport infrastructure investments and scarce resources (Berg, Deichmann, Yishen, & Harris, Transport Policies and Development, 2016). All of these challenges should be taken into consideration while developing a policy to ensure its successful implementation.

Policy options

Most of the interviewees (3 out of 5) were unaware of the policy options used to minimize GHG emissions in the transport sector. However, a few interviewees suggested initiatives that could be used for policy options such as electronic-ticketing (E-ticketing) policy and electric vehicles ticketing. One respondent said that electronic payments had been implemented to reduce the use of paper as a way to reduce tree cutting. The key informants added that the policy that could be used to assist in emission reduction is introducing a dedicated bus lane to prioritize public vehicles. This bus lane could be achieved by expanding roads and choosing which lane should be used by only public transport. "*For instance, there is a road 54, as shown in caption 1, which has been expanded into one of the corridors. Implementing such a policy on that road would be a way of reducing public transport time spent on a journey hence reducing emissions*." Mentioned by one of the respondents.

Caption 1: Showing road 54 that has been expanded to provide a dedicated bus lane

Source: Author's field data (2020)

Location and time: Road 54 (Rwandex) with 3 lanes, 21st September 2020 at 11:00 am

One of the respondents believed that introducing a carbon tax in the transport sector reduces emissions in Kigali. Carbon taxing will force public transport operators and private vehicle owners to imitate behaviors and initiatives to cut off their emissions. Another respondent mentioned that another way of reducing emissions in Kigali city is to apply fuel taxes, especially in private cars. The majority of interviewees (4 out of 5) emphasized implementing the fuel tax; an in-depth study must be carried out to determine who should pay and how much should be paid. Congestion pricing was also identified by one of the respondents as another policy instrument that could be useful in reducing emissions in Kigali city.

Several policy options could be adopted and have a significant reduction in GHG in urban transport. These policies could be achieved in two ways: technological change to reduce carbon content per VKT and transport-mode shift from private cars to transit (Safonov, Frenay, & Hecq, 2003). Those policy options include, but are not limited to, energy pricing, fiscal policy, taxes on transportation congestion pricing. Pricing instruments are normally aimed at pricing transport at its real economic price (Button 1993; Goodwin, Dargay, and Hanly 2004).

The pricing of energy based on its carbon content is a crucial policy instrument to trigger these changes to reduce GHGs in the long run. Energy pricing could be achieved through a carbon tax or through "cap and trade (Safonov, Frenay, & Hecq, 2003). Promoting this policy will increase the demand for using transit or public vehicles hence reducing Vehicle Kilometer traveled (VKT). However, if alternative energy such as renewable energy is not available at a competitive price, this will not be achieved successfully. This policy is not decided at the local level; it only depends on national policy and increasingly on international agreements. Applying the pricing policy in Kigali will require the government of Rwanda especially the ministry of environment to promote alternative fuels and renewable energy, such as biofuels or electric vehicles. Additionally, carbon content on all imported fuel should be analyzed by Rwanda standards Boards (RSB) and changed into much better quality to reduce emissions.

The fiscal policy instrument is an active instrument towards improving fuel economy and reducing fuel use. This policy is only successful once combined with regulations (standards & laws) and education (labeling & advertising) (World Summit on Sustainable Development, 2010). In addition, low carbon fuel standards can be used under a fiscal policy to set goals for reducing the life cycle of GHG intensity for the entire transportation fuel pool. The instrument allows the manufacturer to produce and retails to purchase the mix of fuels that meet the standards (OECD, 2015). Those that can reduce their emissions can then generate and sell carbon credits. Fiscal policies such as carbon taxes can be achieved by incorporating environmental damages into the price of fuels. The implementation of fiscal policy will require the introduction of emissions standards by the Rwanda Environmental Management Authority (REMA) where everyone is aware of the maximum limits of allowed emissions per vehicle or person. These standards could help the government limit emissions at a certain amount, hence reducing the overall GHG emissions in Rwanda.

Additionally, taxes on transportation fuel can be used as another option to reduce emissions. Taxes differ depending on fuel types (e.g., gasoline, diesel). Linking the taxes to the GHG emissions in monetary value based on a tone of CO_2 equivalent per unit of energy can drive technological innovation in low carbon (Pew center Congressional Policy Brief, 2008). Bulgaria has applied this instrument of fuel taxes, and it contributed to the reduction of transport fuel consumption, hence the emissions reductions (World Summit on Sustainable Development, 2010). Implementing taxes on transport in Rwanda will require the Rwanda

Revenue Authority (RRA) to develop a policy of transport taxes for different vehicles category and provide exemptions for public transport. The implementation of this policy can be monitored by RRA and RURA (Rwanda Utility Regulatory Authority) where a certain fee is attached for all transport categories especially private vehicles.

Congestion pricing involves increasing fees for road usage until the desired decrease in congestion is achieved. It does not aim at recovering the cost of a highway, but at limiting traffic volume to obtain the desired speed (Safonov, Frenay, & Hecq, 2003). However, congestion pricing has some limitations, such as substantial technical investment in its installation and operation. It also has high transaction costs, which might significantly reduce the income of the operators. Singapore was an early leader in adopting congestion charging. Following a one-year public dialogue in 1975, Singapore implemented a paper system of daily licenses for vehicles entering the central zone during peak traffic periods (Pike, 2010). The system was significantly renovated in 1998 with the introduction of Electronic Road Pricing (ERP). In that year, traffic entering the zone dropped to 31 percent below original levels even as employment in the city had increased by a third and vehicle ownership by seventy-seven percent (Keong, 2002). Bus ridership increased by about 20 percent due to congestion charging, transit improvement, and related policies.

Congestion pricing can be used to reduce traffic jams in the main routes of Kigali to reduce GHG emissions. Rwanda Utility Regulation Authority (RURA) can implement the congestion policy of redirecting private vehicles in other minor routes and allowing public transport to use the main roads and those willing to pay the price. However, the pricing policy should be analyzed carefully to produce the desired results.

4.2.3 Objective 4: Strategies for promoting the use of public transport in Kigali

This section focuses on objective 4,

Mode of transport, GHG emissions, and transport preferences

Some interviewees (2 out of 5) believed that all modes of transport in Kigali contribute to the emissions. However, the majority believed that motorcycles are the main contributors to GHG emissions under the public transport sector because they are many in numbers. Most of the interviewees (3 out of 5) mentioned that Kigali passengers prefer motorcycles because they can reach down in the village where the road network is not available. "… *The motorcycles in Kigali feed public buses; that is why many passengers prefer motorcycles as a mode of transport in Kigali*…" one respondent cited. Many people use the motorcycle in Kigali, and motorcycles are expensive compared to the buses and not safe; this shows how the Kigali bus sector is working well below capacity (Bajpai, 2014). According to the 2013 MININFRA report, out of 118,656 vehicles registered in Rwanda, 48.86% were motorcycles. The emission of motorcycles was the dominant contributor to the total GHG emissions from the transport sector.

Public transport safety and crime

All of the interviewees viewed public transport in Kigali as the safest. One respondent said, "…*There are not many concerns related to any crime in public transport…"*He continued, *"The only concern was raised about the number of available public buses and time spent on a queue waiting for the bus*." The insufficient mode of transport in Kigali was the only complaint about public transport. Respondents mentioned that the Rwanda National Police (Traffic police department) implemented strategies to reduce incidents in public transport. Those strategies include tracking systems that have been installed in public vehicles, to identify and track the location of all public vehicles.

The occurrence of accidents and incidents in the transport sector, as reported by Rwanda national police, shows that motorcycles take the lead in causing road traffic accidents. Seventy-one percent of the total road traffic accidents registered since January 2017 were caused by motorcycles (MININFRA, 2018). The report showed that transport safety is predominantly severe in road transport because motorized and non-motorized traffic often share the same space while having differing operating speeds, knowledge of traffic regulations, and protection levels. Public transport operators and vehicle drivers should adhere to road traffic rules to reduce accidents caused by motorized traffic.

The Kigali urban master plan from2013 to 2018 on the 5th year of its implementation improved pedestrian safety based on the systematic implementation of sidewalks. It also introduced safe pedestrian crossings (RTDA, 2020). Pedestrian crossings reduced the number of accidents between vehicles and walking passengers drastically.

Rwanda introduced electronic payments by cards for buses, taxis, and motorcycles to help monitor and manage passengers who use public transport, resulting in a reduction of crimes. Traffic police departments also helped in implementing speed governor initiatives to reduce public transport accidents. All these initiatives contributed to promoting public transport policy and reducing crime and accidents. Besides, bus management services introduced a queuing system based on arrival time (first come, first served). Bus management services encouraged to order at bus stops and therefore enhanced passenger safety and security in the terminals. Furthermore, some bus terminals were upgraded to separate franchised route loading and unloading (Nkurunziza, 2018).

Good initiative and practices

Most of the interviewees (3 out of 5) mentioned that promoting public transport in Kigali requires increasing the number of public vehicles. The government was helping companies bring in new buses to increase the available buses on the road. The respondents also shared that another initiative was to find a dedicated bus lane in Kigali to reduce travel time. A dedicated bus line could increase public transport use in Kigali since people want to be at work on time and get home without delay due to traffic jams. One of the interviewees reported that a road network is not used fully by private vehicles. These roads should be used at maximum so that buses can have spaces in their dedicated bus lane.

The respondents further mentioned that the growing road network would also contribute to the increased public transport use. Another interviewee argued that there is a BRT project in the pipeline by the city of Kigali to promote public transport. Some interviewees suggested that Personal Rapid Transit (PRT) is another way that Kigali city was considering promoting public transport and reducing emissions. One interviewee cited that this project will be piloted by investors in partnership with the government of Rwanda. The respondents believed that PRT would be a way of reducing motorcycles that are used where there is no road network to feed buses. Furthermore, the interview mentioned that another option of introducing the internet in buses and e-ticketing was done based on the existing fiber internet propagation (Nkurunziza, 2018a). All of these initiatives promoted public transport in Kigali and increased passengers that used public transport.

Most of the interviewees (3 out 5) shared a view on the initiative to promote public transport in Kigali; these include internet in the bus, modernized and secured bus shelters, electronic payment, and monitored and organized public transport operators. These initiatives increased the number of people using public transport in Kigali. Respondents also mentioned another initiative that can be implemented to promote public transport is to increase its reliability. Also, the respondent shared that the initiative of introducing Bus Information Systems (BIS) on bus shelters and online platforms could boost the number of people using public transport.

The interviewees reported that in the direction of promoting public transport in Kigali, the government would consider a way of developing regulations on how public transport can be promoted. For instance, introducing diversification of public transport services could attract passengers whose demands vary (Berg, Deichmann, Yishen, & Harris, Transport Policies and Development, 2016). For example, introducing PRT (Personal Rapid Transit) and express buses on the existing network can provide the types of service in terms of speed and price that accommodate the various demands. Additionally, passengers should be aware of the benefits of using public transport, such as an awareness campaign to the public on different benefits such as financial savings to households, and a lower burden to the environment. All the benefits of using public transport must be communicated together with all the facilities and improved services. For instance, Bus Information System (BIS) could be used to inform bus passengers on the bus schedule. Passengers will know when the next bus should arrive; hence, it would improve public transport reliability. The passengers can then be able to plan their day. This will likely increase the number of passengers.

Road network and infrastructure

Some of the interviewees (2 out of 5) mentioned that the Kigali road transport and infrastructure network factors influence public transport's use and performance. For instance, the lack of a dedicated bus lane contributed to the bus delays and long waiting in the vehicles and the queue. There were insufficient road networks in Kigali that pushed passengers to use other transport modes such as private vehicles. One of the interviewees cited that the government should own the initiative of promoting the use of public transport by improving road networks and infrastructure. The respondent also mentioned that the government should engage partners in developing public transport infrastructure such as BRT roads. Also, engaging in developing dedicated bus lanes can contribute to promoting public transport in Kigali.

In 2018 the city of Kigali was in the 5th year implementing the Kigali Urban Master Plan of 2013. The implementation led to the development of road infrastructure. As part of this process, significant improvements to key elements of the urban mobility network and urban mobility system were being planned or were already underway. The most significant achievements included: a large number of roads that have been paved; a significant road widening program to introduce dedicated bus lanes in the highly congested parts of the city's road network is under construction, and some of the roads were completed. Moreover, vehicle flow improvement at critical intersections in the city was being planned (RTDA, 2020).

Maximum walking distance

Most of the interviewees (3 out of 5) said that the population in Kigali walked nearly five hundred meters to the nearest bus station. However, Kigali city's journey towards reducing GHG and promoting public transport use has been improved drastically. According to the study by Nkurunziza (2018), more than 22 new routes have been created following 41 initial routes, and the existing routes extended to reach residential areas in a bid to reduce walking distances to the nearest bus stops. Furthermore, many bigger buses have been purchased replacing the former smaller minibusses, which served the feeder routes.

Time spent in travel

The respondents shared that the average time spent traveling in Kigali city on the bus or a taxi cab was forty-five minutes to one hour during peak time. The delay was caused by a traffic jam as captured in one of Kigali roads near the Kigali heights building in caption 2 below. The majority of the interviewees (4 out of 5) emphasized that the average travel time by motorcycle was twenty to thirty minutes to reach a given destination during peak time. There was a lack of streamlined bus schedules that delays passengers at stops and terminals (MININFRA, 2018). As a result, that prevented passengers from cutting down on their transit time and costs and, hence, increased travel time.

Caption 2: Showing traffic jam during peak hour in the evening in one of Kigali road near Kigali Heights building

Source: Author's field data (2020)

Location and time: Kigali heights road, 21st September 2020 at 6:00 pm (Peak hours)

Number of transfer and accessibility

Most of the interviewees (3 out of 5)reported that the average number of transfers was two transfers while traveling on a bus. Motorcycles usually did not have transfers. The majority of the interviewees mentioned that the average number of stops when using buses in Kigali city is six to ten on one route. A report done by MININFRA in 2018 stated that to reach a destination, a passenger is often forced to take multiple routes, each with different schedules and transfer stations but without coordination with passenger information. Consequently, passengers sometimes use long walks to make transfers and pay multiple fares (MININFRA, 2018).

Comfort in using public transport

Most of the interviewees (3 out of 5) mentioned that the average age of motorcycles used in Kigali was 2 to 3 years old. Most motorcycles were new; they are hence comfortable for passengers to use. The respondents also shared that buses used in Kigali had an average of 5 to 10 years old, they were also generally comfortable. However, taxi cabs were very old between 15 to 25 years old. "*It is a little bit uncomfortable using taxi cabs in Kigali" cited one of the respondents*. He also mentioned that some taxi drivers have been told by the Rwanda Utility Regulatory Authority (RURA) to buy new vehicles. Respondents mentioned that Kigali had other companies that brought in brand new vehicles in taxi cabs and they are comfortable for passengers. Excluding motorcycles, the average age of cars in Rwanda in 2018 was 19 years, with more than half of the cars made before 1999, and 95.2 percent of vehicles were more than ten years old (Duhuze, 2018).

Barriers and limitations of using public transport

One of the interviewees cited that weather is a limiting barrier to using open public transport such as motorcycles. It happens mainly in the rainy season. Weather is one of many other reasons that people prefer using private vehicles in Kigali city. The majority of the interviewees (4 out of 5) viewed public transport reliability as another barrier for passengers to use public transport, mainly buses. There was neither Bus Information System (BIS) that indicated the approximate time that one can spend on the bus nor the waiting time for the next bus. Another limiting factor from using public transport was their limited number, which caused the long wait in queues shown in caption 3 below.

Caption 3: Showing passenger queues waiting at the bus in Kigali downtown bus stop

Source: Author's field data (2020)

Location and time: Kigali downtown bus stations, 20th September 2020 at 5:30 pm (Rush hour)

Respondents cited that the challenge associated with an imbalance between road traffic and available road infrastructure also contributes to the barriers and limitations of using public transport in Kigali. Also, Public transport in Kigali was characterized by delays, inaccessibility, and unpredictability (MININFRA, 2018). Therefore, those challenges limited some passengers from using public transport in Kigali.

A passenger survey done by RTDA in 2020, which aimed at providing the passenger level of satisfaction indicated that the main barriers and limitations towards promoting the use of public transport in Kigali are services, waiting time, and somewhat vehicle conditions (RTDA, 2020). Also, it showed that the lack of Bus Information System led to long waiting times and poor services and limited the number of people using public transport. However, the City of Kigali introduced Bus management services in all car parks. Bus management services were made by a queuing system based on arrival time (first come, first served). This system encouraged the order of bus stops, and it enhanced passenger safety and security at the terminals. Some of the terminals were upgraded to separate franchised route loading and unloading (Nkurunziza, 2018).

Information

One of the interviewees mentioned that travel information is disseminated to the passengers by the drivers for normal circumstances. However, in case of abnormal conditions, RURA is in charge of disseminating information to the passengers. The respondent reported that the information is spread through the bus owners, drivers in the meeting with the authorities. The message is then dispersed to the passengers via radio, television, or social media.

4.3 Study limitations

It was challenging to collect data, especially on vehicle activities such as kilometers traveled and fuel consumption. The bus companies, motorcycle owners, and taxicabs drivers were not aware of GHG emissions and climate change in general; hence they were so reluctant in providing such information. This challenge was addressed by applying for the research permit from the National Commission of Science and Technology; this gave the researcher credibility to get the necessary data. Additionally, before collecting any data the researcher took some time to explain more about GHG emissions and how the data shall be used. The collected data were cross-checked with that of Rwanda Regulation Authority (RURA) and Rwanda Transport Development Agency (RTDA) for data quality.

The greenhouse gas inventory report in this study was developed and structured according to the UNFCCC convention and in compliance with the 2006 IPCC guidelines. GHG emissions and their uncertainties were estimated for a period between 2012 and 2019 for the transport sector. In general, Tier 1 methodology was applied to estimate emissions of direct greenhouse gases (CO_2, CH_4, and N_2O). However, there were different sources of uncertainties such as the use of default value provided in the IPCC software since Rwanda doesn't have a national specific emission factor. Hence, it should be recommended that, in future inventories, an effort should be made to develop the country's specific emission factors to overcome high uncertainties in estimated emissions. To address this challenge the result of this study on the estimated GHG emissions was compared with the estimated GHG emissions by Rwanda Environmental Managements for validity.

The pandemic COVID 19 was a limiting factor during data collection. The pandemic started in the middle of data collection and the researcher had to stop the data collection process until the key informants and vehicle owners were released from the lockdown. It delayed the researcher in completing the dissertation on time. Securing the appointment with key informants for the interview was a challenge as well, even after the lockdown due to the pandemic. The challenge was addressed by sending the questionnaire via email and scheduled the meeting after they were familiar with the topic. Also, having worked in the Rwanda transport sector for three years allowed the researcher to use the connection she had to contact the key informants directly.

Summary and Conclusion

This chapter answered all the research questions and discussed related literature. The emissions of public transportation in Kigali were estimated, and motorcycles were the most contributors to GHG emissions under public transport. The interviewees shared their views on policy options and emissions reduction options that could be implemented in Kigali city. The first research objective about GHG emissions of public transport in Kigali was estimated from 2012 to 2019. It was noted that there was an increase in GHG emissions from public transport in Kigali, where the year 2012 had 45.26 Gg in C02 equivalent, and the year 2019 had 98.92 Gg in C02 equivalent. Additionally, the study identified GHG emissions reduction options for public transport in Kigali for the second objective. These included introducing electric vehicles in public transport, the shift to mass transportation, and the introduction of Bus Rapid Transit (BRT).

Also, this study determined transport policy options for public transport in Kigali from the third objective. Different policy options are implemented in Kigali public transport to reduce emissions, such as electronic payment (E-ticketing) policy, dedicated bus lane. In addition, other policies identified could be used to reduce emissions such as energy pricing, fiscal policy, taxes on transportation, and congestion pricing.

From the fourth objective, the study explored strategies for promoting public transport in Kigali. Different recent innovative initiatives and best practices for promoting the use of public transport were implemented in Kigali. Those strategies include tracking systems that have been installed in public vehicles, electronic payments.

Furthermore, Rwanda introduced the implementation of speed governor's initiatives to reduce public transport accidents. Another initiative of bus management services introduced a queuing system based on arrival time, which encouraged order at bus stops and enhanced passenger safety and security in the terminals. The chapter also summarizes the limitation undergone during the data collection of this study. The next chapter summarizes the findings and gives recommendations that could help minimize GHG emissions and promote public transport.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 GHG emissions from public transport 2012-2019

In the first objective, this study estimated GHG emissions of public transport in Kigali from the year 2012 to 2019. The findings showed that there was an increase in the trend of GHG emissions from public transport in Kigali. The following table summarizes GHG emissions from public transport in Kigali from 2012 to 2019.

Table 5. 1 Total GHG emissions and emission per vehicle category for public transport vehicles in Kigali

Year	Total GHG Emissions	Taxicabs	Bus	Motorcycle
2012	45.26	1.38	6.87	37.01
2013	51.50	1.82	8.73	40.94
2014	72.20	2.26	25.09	44.84
2015	78.41	3.21	26.43	48.77
2016	89.89	4.18	32.66	53.05
2017	98.13	4.65	36.78	56.70
2018	95.37	5.16	29.36	60.85
2019	98.92	4.69	27.32	66.92

Source: Author's field data (2020)

Motorcycles showed the highest GHG emissions compared to other vehicles, followed by buses. Therefore, motorcycles were the most dominant contributors to GHG emissions in public transportation. The results proved that GHG emissions in public transport are increasing tremendously most likely because of the increase in vehicle numbers. It implies that the emissions will increase with the new vehicle number as the population of Kigali grows.

5.1.2 GHG emissions reduction options for public transport

From the second objective, this study identified GHG emissions reduction options for public transport in Kigali. There were several climate change mitigation measures or emission reduction techniques used in Kigali public transport. The introduction of electric vehicles in public transport and the shift to mass transportation reduces emissions in public transport. Additionally, introducing the BRT system in Kigali will promote the public transport sector, reducing the number of private cars. Another emission reduction option that could be used is the use of alternative fuels such as biofuels in public transport as an environmental instrument to reduce emissions. Furthermore, improving vehicle efficiency through vehicle and fuel quality regulations and taxation can be used as a political instrument to reduce emissions in public transportation.

5.1.3 Public transport policy options

This study determined public transport policy options in Kigali from the third objective. Different policy options are being used in Kigali public transport to reduce emissions, such as the electronic payment (E-ticketing) policy. Electronic payments were implemented to reduce the use of paper as a way to reduce tree cutting. Introducing a dedicated bus lane is another policy option that is in the pipeline. This bus lane could be achieved by expanding roads and choosing which lane should be used by only public vehicles. Besides, there are other numbers of policies that could be adopted and could have a significant impact in reducing GHG in Kigali public transport. Those policy options are energy pricing, fiscal policy, taxes on transportation, and congestion pricing. Formulated transport policies for urban public transport in Kigali have been implemented to the extent of nearly 100%. For instance, the policy on limiting the importation of old cars or used cars in Rwanda by adding vehicle tax as a fine for an old or used imported car.

Furthermore, regulation on direct vehicle GHG emissions measurements and promoting public transport was formed by REMA, and it has been followed for the past years. It is mandatory for all vehicles operating in Rwanda except motorcycles. The emissions measurements are done twice a year for commercial and public transport vehicles and once a year for other vehicles (private, public, and even utilities). The law helped control emissions in the transport sector. Another policy on public transport strategies that was approved in 2012 for generation one has been fully accomplished. Therefore, there is an ongoing public transport policy of generation two developing due to the successful implementation of generating one.

5.1.4 Strategies for promoting the use of public transport

From the fourth objective, the study explored strategies for promoting the use of public transport in Kigali. Different recent innovative initiatives and best practices for promoting the use of public transport were implemented in Kigali. Those strategies include a tracking system that has been installed in public vehicles, to identify and track the location of all public vehicles. Additionally, the strategy of electronic payments was introduced in all public transport vehicles (buses, Motorcycles, and Taxi cars). Electronic payments helped to monitor and manage passengers who use public transport. It resulted in a reduction of crimes such as robbery at the bus station. Rwanda introduced implementing speed governor initiatives to reduce public transport accidents. Another initiative of bus management services introduced a queuing system based on arrival time, which encouraged order at bus stops and enhanced passenger safety and security in the terminals. Some of the terminals were upgraded to separate franchised route loading and unloading. Furthermore, Kigali public transport was promoted by introducing free internet on the bus, modernized and secured bus shelters, and monitoring and organizing public transport operators.

Besides those initiatives and best practices, there have been some barriers that limited the use of public transport in Kigali. The main barriers and limitations towards promoting the use of public transport in Kigali were services, waiting time, and somewhat vehicle conditions. The lack of bus information systems led to long waiting times and reduced services, which limited the number of people using public transport. Furthermore, the lack of a dedicated bus lane contributes to long-time travel. Moreover, there were insufficient road networks in Kigali city that pushed passengers to use other transport modes such as private vehicles.

Furthermore, the weather, such as the rainy season was a limiting barrier to use open public transport such as motorcycles. There is neither a Bus Information System (BIS) that indicates the approximate time that one can spend on the bus nor the waiting time for the next bus. Another limiting factor from using public transport was the limited number of public vehicles, which caused a long wait in the queue.

5.2. Recommendations

I. Measures should be taken by the Rwanda Ministry of Infrastructure (MININFRA) to reduce emissions in the public transport sector by considering alternative fuels such as hybrid cars and renewable energy.

II. *The government should promote the shift to mass public transport (bigger buses) for 70 passengers or more to cut off emissions in public transport*. It was noted that in 2018 where small buses (29 passengers) were replaced by big buses (70 passengers) resulted in a decrease in total GHG emissions. Bigger buses may result in smaller GHG emissions per capita – because many passengers share the fuel consumed. As the bus gets older emissions will keep increasing due to the reduced performance of the vehicles.

III. *The City of Kigali (CoK) should provide incentives for mass transit and transport services. The city of Kigali should also promote new technologies to reduce emissions, such as encouraging the use of hybrid vehicles and other public transport means (e.g. Personal Rapid Transit).* Bus Rapid Transit (BRT) could contribute to a significant emission reduction in public transport; however, it requires substantial investments. Introducing BRT in Kigali could bring a significant change in fuel consumption, congestion, and an increasing number of passengers using public transport. However, the potential in Kigali with about 1 million inhabitants is limited for such significant investment and transformation. Hence the mass transportation can be implemented first and other initiatives before Kigali city invest in BRT.

IV. Rwanda's Ministry of Environment should develop an energy pricing policy with competitive pricing to increase public vehicles' demand. This will reduce Vehicle Kilometer Travelled (VKT) and help in reducing GHG emissions in the transport sector.

V. The government of Rwanda should promote alternative fuels and renewable energy, such as biofuels and electric vehicles. Additionally, carbon content on all imported fuel should be analyzed by the Rwanda Standards Board (RSB) and changed into much better quality to reduce emissions.

VI. Rwanda Ministry of Environment should develop and implement fiscal policy and taxes on transportations in Rwanda. This will require extensive education and sensitization through the ministry of the environment. It also requires the introduction of emissions standards where everyone is aware of the maximum limits of allowed emissions per vehicle or person. These standards will help the Government limit emissions at a certain amount, hence reducing the overall GHG emissions in Rwanda.

VII. Rwanda's Ministry of Infrastructure should consider all possible challenges while developing or implementing transport policies. The main challenges for developing countries include funding for transportation infrastructure investments and scarce resources.

VIII. The government of Rwanda should introduce a Bus Information System (BIS) in the public transport sector to promote public transport use.

IX. The government of Rwanda should introduce a dedicated bus lane in Kigali to reduce the time spent on a journey and to increase public transport reliability.

X. The government of Rwanda should facilitate or introduce alternative transport on open public vehicles such as motorcycles in rainy seasons.

XI. The government of Rwanda should develop a uniform fare to save both passengers’ transfer time and costs.

Table 5. 2 Summary of Key Findings and Recommendations

Objective 1: To estimate GHG emissions of public transport in Kigali from 2006 to 2018	
Key findings	**Recommendations**
GHG emissions in public transport increase tremendously due to the increase in vehicle numbers (45.26 Gg in C02 equivalent in 2012 and 98.92 Gg in C02 equivalent in 2019). The shift towards the big buses with 70 passengers resulted in a decrease in total GHG emissions. Motorcycles were found to be the most dominant contributors to GHG emissions in public transportation	Measures should be taken by the Rwanda Ministry of Infrastructure (MININFRA) to reduce emissions in the public transport sector by considering alternative fuels such as hybrid cars and renewable energy. The government should promote the shift to mass public transport (bigger buses) for 70 passengers or more to cut off emissions in public transport. The government of Rwanda should promote alternative fuels and renewable energy, such as biofuels and electric vehicles

Objective 2: To identify GHG emissions reduction options for urban public transport in Kigali	
Key findings	**Recommendations**
1.Climate change mitigations measures: The introduction of electric vehicles in public transport The shift to mass transportation, the introduction of the BRT system Use of alternative fuels such as biofuels Improving vehicle efficiency through vehicle and fuel quality regulations and taxation 2. Political, environmental, and economic instruments to reduce GHG emissions: Subsidies for low carbon-intensive vehicle emissions standards and regulation	The government of Rwanda should provide incentives for mass transit and transport services, and promote new technologies to reduce emissions, such as encouraging the use of hybrid vehicles Carbon content on all imported fuel should be analyzed by the Rwanda Standards Board (RSB) and changed into much better quality to reduce emissions. Rwanda Ministry of Environment should develop an energy pricing policy with competitive pricing to increase the demand for public vehicles

Objective 3: To determine transport policy options for urban public transport in Kigali	
Key findings	**Recommendations**
Policy options to reduce public transport emissions: Introducing a dedicated bus lane Fiscal policy Taxes on transportation Congestion pricing	Rwanda Ministry of Environment should develop and implement fiscal policy and taxes on transportations in Rwanda Rwanda's Ministry of Environment should develop an energy pricing policy with competitive pricing to increase the demand for public vehicles.

2.Implementation of the existing transport policy Regulation on direct vehicle GHG emissions measurements and promoting public transport Vehicle tax as a fine for an old or used imported car	Rwanda Ministry of Infrastructure should consider all possible challenges while developing or implementing transport policies

Objective 4: To explore strategies for promoting the use of urban public transport in Kigali	
Key findings	**Recommendations**
Recent innovative and best practices for promoting the use of public transport: Vehicle tracking system Electronic payments Speed governor's initiatives Introduced a queuing system based on arrival time Terminals were upgraded Introduced free Wifi in the buses Modernized and secured bus shelters Monitoring and organizing public transport operators.	I. The government of Rwanda Introducing a dedicated bus lane in Kigali will reduce the time spent on a journey, increasing public transport reliability
2. Barriers and limitations to promoting the use of public transport in Kigali: The lack of bus information systems Insufficient road networks in Kigali city The weather such as raining season was a limiting barrier to use open public transport A limited number of public vehicles Lack of dedicated bus lane	I. The government of Rwanda should introduce Bus Information System (BIS) in the public transport sector to promote the use of public transport II. The government of Rwanda should facilitate or introduce alternative transport on open public vehicles such as motorcycles in rainy seasons III. The government of Rwanda should develop a uniform fare to save both passengers' transfer time and costs.

Source: Author's field data (2020)

Recommendations for Future Research

In the past few years, there has been an increase in private vehicles in Kigali city, and traffic jams have increased drastically. There should be a study on estimating emissions of private vehicles in Kigali city. This study focused on estimating emissions of public vehicles and suggested a policy on how those emissions can be reduced while promoting public transport. There is still a gap in estimating emissions of private vehicles in Kigali city. Hence studies are required to determine the estimated GHG emissions of private vehicles.

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Lists of Annexes

Annex 1: Sampled motorcycles operating in Kigali

Location	Year of manufacturer	Working days/Week	km/week	Fuel/week
Nyarugenge	2011	7	1050	35
Nyarugenge	2012	5	750	15
Nyarugenge	2012	4	800	16
Gasabo	2012	6	1200	18
Nyarugenge	2013	5	750	15
Nyarugenge	2013	6	1200	30
Nyarugenge	2014	6	1200	24
Nyarugenge	2014	5	1000	15
Gasabo	2015	6	750	24
Nyarugenge	2015	7	1400	35
Gasabo	2015	3	300	6
Gasabo	2015	6	1800	30
Kicukiro	2015	5	750	17.5
Gasabo	2015	6	1200	18
Kicukiro	2015	5	1000	25
Gasabo	2015	6	900	30
Gasabo	2015	6	600	18
Nyarugenge	2016	6	780	27
Nyarugenge	2016	7	1400	21
Nyarugenge	2016	5	1000	20
Kicukiro	2016	6	1200	30
Nyarugenge	2016	6	1200	27
Nyarugenge	2016	6	1200	24
Gasabo	2016	6	1080	30
Kicukiro	2016	6	900	18
Gasabo	2016	6	900	24
Gasabo	2016	7	1050	28
Nyarugenge	2016	6	1200	24
Nyarugenge	2017	6	900	18
Kicukiro	2017	6	720	24
Nyarugenge	2017	6	1200	30
Gasabo	2017	5	750	15
Nyarugenge	2017	7	1750	35
Nyarugenge	2017	5	750	20
Nyarugenge	2017	7	2100	28
Nyarugenge	2017	6	1200	24
Gasabo	2017	6	1200	30
Gasabo	2017	6	900	24
Gasabo	2017	5	750	15
Gasabo	2017	6	1200	24
Nyarugenge	2018	5	1000	15

Nyarugenge	2018	6	1200	24
Kicukiro	2018	7	1400	14
Gasabo	2018	5	1000	15
Gasabo	2018	4	1000	8
Nyarugenge	2018	6	1800	24
Nyarugenge	2018	6	1200	27
Nyarugenge	2018	6	1200	24
Nyarugenge	2018	6	1080	24
Gasabo	2018	5	1000	20
Nyarugenge	2018	6	900	24
Gasabo	2018	6	1200	24
Gasabo	2018	5	1000	25
Gasabo	2018	6	1200	30
Gasabo	2018	6	720	30
Gasabo	2018	6	1200	24
Gasabo	2018	6	1200	24
Gasabo	2018	7	1400	28
Nyarugenge	2018	5	750	15
Nyarugenge	2018	6	900	30
Gasabo	2018	5	750	25
Gasabo	2018	5	1000	15
Gasabo	2019	6	600	24
Gasabo	2019	5	1250	20
Gasabo	2019	5	1000	22.5
Gasabo	2019	7	1050	35
Gasabo	2019	6	900	18
Nyarugenge	2019	6	1200	24
Gasabo	2019	5	750	20
Nyarugenge	2019	5	1000	20
Nyarugenge	2019	6	1272	24
Gasabo	2019	6	900	30
Gasabo	2019	6	900	30
Nyarugenge	2019	5	750	15
Nyarugenge	2019	6	1500	30
Nyarugenge	2019	5	750	15
Nyarugenge	2019	6	1200	30
Kicukiro	2019	6	1200	24
Kicukiro	2019	6	1200	24
Gasabo	2019	6	1200	30
Gasabo	2019	5	1000	20
Kicukiro	2019	6	900	18
Gasabo	2019	7	1400	21
Gasabo	2019	6	900	30
Kicukiro	2019	4	600	12
Kicukiro	2019	6	900	30
Gasabo	2019	6	1200	30

Gasabo	2019	6	1200	30
Gasabo	2019	5	750	25
Gasabo	2019	6	900	30
Kicukiro	2019	6	900	24
Nyarugenge	2019	6	900	24
Nyarugenge	2020	6	1080	30
Nyarugenge	2020	6	1200	30
Kicukiro	2020	6	1200	24
Gasabo	2020	4	800	20
Gasabo	2020	6	900	24
Nyarugenge	2020	6	900	24
Gasabo	2020	6	900	24

Annex 2: Sampled taxicabs operating in Kigali

Location	Vehicle type	Fuel type	Year of man	N seats	N days/week	km/week	Fuel/week
Nyarugenge	T Corolla	Gasoline	1991	4	7	490	49
Gasabo	T corolla	Gasoline	1991	4	6	600	42
Nyarugenge	T Carina	Gasoline	1993	4	6	300	30
Nyarugenge	T Corolla	Gasoline	1993	4	6	480	60
Gasabo	T Carina	Gasoline	1993	4	6	360	36
Gasabo	T Carina	Gasoline	1993	4	6	360	36
Gasabo	T Carina	Gasoline	1993	4	6	360	36
Gasabo	T Carina	Gasoline	1993	4	6	360	36
Gasabo	T Carina	Gasoline	1993	4	6	360	30
Gasabo	T Carina	Gasoline	1993	4	6	360	60
Gasabo	T Carina	Gasoline	1993	4	6	360	60
Gasabo	T Carina	Gasoline	1993	4	6	360	60
Gasabo	T Corolla	Gasoline	1993	4	6	600	48
Nyarugenge	T Carina	Gasoline	1994	4	5	250	25
Nyarugenge	T Carina	Gasoline	1994	4	6	420	30
Nyarugenge	T Carina	Gasoline	1995	4	5	350	50
Nyarugenge	T Carina	Gasoline	1995	4	6	360	30
Nyarugenge	T Carina	Gasoline	1996	4	5	250	25
Gasabo	T Carina	Gasoline	1996	4	6	360	30
Gasabo	T Carina	Gasoline	1996	4	6	360	30
Gasabo	T Carina	Gasoline	1996	4	6	360	30
Gasabo	T Carina	Gasoline	1996	4	6	360	30
Nyarugenge	T Carina	Gasoline	1997	4	6	600	90
Nyarugenge	T picnic	Gasoline	1997	4	7	560	49
Nyarugenge	T Carina	Gasoline	1997	4	6	600	60
Nyarugenge	T Carina	Gasoline	1997	4	6	360	30
Gasabo	T Carina	Gasoline	1997	4	6	360	60
Gasabo	T Carina	Gasoline	1997	4	6	360	60
Gasabo	T Carina	Gasoline	1997	4	6	360	60
Nyarugenge	T Avensis	Gasoline	1998	4	5	225	25
Nyarugenge	T Avensis	Gasoline	1998	4	6	600	60
Gasabo	T picnic	Gasoline	1998	4	6	360	30
Nyarugenge	T Avensis	Gasoline	1999	4	6	360	30
Gasabo	T picnic	Gasoline	1999	4	6	360	42
Nyarugenge	T Avensis	Gasoline	2000	4	6	360	30
Nyarugenge	T Avensis	Gasoline	2000	4	6	360	30
Gasabo	T picnic	Gasoline	2000	7	6	420	48
Nyarugenge	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60

Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Gasabo	T picnic	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60
Kicukiro	T Avensis	Gasoline	2002	7	6	600	60

Annex 3: Summary table of total fuel consumptions for public transport in Kigali

YEAR	CARS	FUEL TYPE	MOTO	FUEL TYPE	BUS	FUEL TYPE
2012	589,838.89	GASOLINE	15,908,646.00	GASOLINE	2,682,594.60	DIESEL
2013	784,378.07	GASOLINE	17,592,525.00	GASOLINE	3,398,888.92	DIESEL
2014	969,878.74	GASOLINE	19,276,404.00	GASOLINE	9,781,279.76	DIESEL
2015	1,383,145.99	GASOLINE	20,960,283.00	GASOLINE	10,308,499.04	DIESEL
2016	1,793,533.25	GASOLINE	22,802,469.60	GASOLINE	12,737,129.44	DIESEL
2017	2,006,246.18	GASOLINE	24,370,860.00	GASOLINE	20,279,514.92	DIESEL
2018	2,214,804.17	GASOLINE	26,149,593.07	GASOLINE	11,447,277.52	DIESEL
2019	2,009,126.18	GASOLINE	28,756,081.70	GASOLINE	10,659,994.24	DIESEL

Annex 4: Semi-structured questionnaire for the key informants

Topic: "Urban transport and climate change mitigation options to minimize greenhouse gas emissions and to promote sustainable use of public transport in Kigali, Rwanda".

My name is Irene Iradukunda and I am pursuing a master's degree in Environmental Science at the University of Botswana. The topic of my proposed work is "Urban transport and climate change mitigation options to minimize greenhouse gas emissions and to promote sustainable use of public transport in Kigali, Rwanda". The study aims to identify transport and climate change mitigation policies to minimize Greenhouse Gas emissions and to promote sustainable use of public transport in Kigali, Rwanda. A significant share of GHG emissions is creating worldwide through transportation. The emissions from vehicles in urban areas are the most significant contributor to GHGs emissions. In Rwanda, GHG removals dominated over emissions for the period between 2006 and 2012 due to AFOLU (Agriculture, forest, and land use). However, Rwanda recorded a rapid increase in GHG emissions during the period between 2013 and 2015 economy, the lifestyle change. The rapid growth of the urban population and the growing use of vehicles caused increased urban traffic congestion and increased GHG emissions (Mbonyinshuti, 2018). This increase in GHG emissions resulted in the rise of average temperature where the year 2012-2014 ranked the rise of 0.79°C with the highest average temperature in Kigali, which progressed from 16°C to 21°C (USAID, 2018). This study will estimate the amount of GHG emissions from public transport in Kigali city. It will also propose possible transport's climate change mitigation policy options.

Specific objective:

1. To estimate GHG emissions of public transport in Kigali from 2006 to 2018
2. To identify GHG emissions reduction options for urban public transport in Kigali
3. To determine transport policy options for urban public transport in Kigali
4. To explore strategies for promoting the use of public transport in Kigali

Date ______ **Name of Interviewer** ______

A: PARTICULARS OF INFORMANT

Name of Informant ______

Duty Station/Location ______

Position/Designation ______

Number of Years of Service ______

Highest Education/Qualification ______

Main Purpose of Job

______

B: PARTICULARS OF THE ORGANISATION

Name of Organization

Organizational Sector (Government/Private/CBO or NGO)

Main Function(s) of Organization

B. Emissions reduction options

1. a) Do you know any emissions reduction measures for public transport?

2. In your opinion, what do you think should be done to reduce GHG emissions in public transport in Kigali?

3. Can you list any top three policy instruments that could be used to assist in emissions reduction in urban public transport in Kigali? Explain?

4. *Use of alternative fuel*. What is the proportion of buses, motorcycles, and cars running on alternative fuels?

C. Transport policy

5. What are the official transport policies, if any, for public transport in Kigali that you are aware of?
6. What sort of transport policy would you recommend should be adopted to promote the use of public transport in Kigali?

7. Explain the level of implementation of the formulated transport policies for urban public transport in Kigali?

D. Promoting the use of public transport

7. *Mode of Transport & GHG Emissions*. In your opinion, which mode of transport contributes more to air pollution and why?

a) Private vehicles
b) Motorcycle
c) Public vehicles

8. a) *Transport Preferences.* Which mode of transport is the most preferred in Kigali and why?

9. *Public Transport Safety*. How safe is it to use public transport in Kigali?

b) What are the top two public transport concerns, if any in Kigali?

10. a) *Public Transport & Crime.* Are there any crime concerns related to public transport that you are aware of?

b) What are the concerns?

c) How could those be mitigated to make public transport more attractive?

11. *a) Good initiatives and practices*. List the recent innovative initiatives and best practices for promoting public transport in Kigali?

    b) Please explain how those initiatives are implemented in Kigali?

    c) Besides those that have been implemented, which initiatives do you think would encourage the use of public transport use in Kigali? Who do you think should undertake its implementation process?

12. *a) Road network and infrastructure*. In your opinion is the Kigali road transport and infrastructure network a factor in influencing the use and performance of the public transport sector? If so, How?

    b) How adequate is the road transport infrastructure and network in Kigali?

    c) How could the road transport infrastructure and network in Kigali be improved to promote the use of public transport?
    d) How could the road transport network and infrastructure be used to improve the performance (efficiency) of the public transport sector in Kigali?

    e) How do you think improved public transport, road networks and infrastructure could affect GHG emissions in Kigali?

12. *Barriers and limitations*. Are there other barriers that you think of that are limiting people to use public transport in Kigali?

13. *Maximum walking distance*. What is the average time to the nearest public transportation station?

14. *Time spent in travel*. What is the traffic volume during peak hours in Kigali and the average time that passengers would spend on travel?

15. *The number of transfers*. How many transfers do the majority of passengers take to reach their final destination?

16. *Comfort using public transport*. What is the average age of public vehicles in Kigali?

17. *Availability.* Are there timetables for public transport in Kigali?

18. *Accessibility.* What is the average number of stops one route has*?*

19. *Time.* What is the average journey time in Kigali?

20. *Information.* How is the travel information disseminated to the passengers for normal and abnormal conditions?

21. *Customer care*. How would you describe the customer care service in public transportation in Kigali?

22. Does your organization have a role to play in ensuring the use of public transport in Kigali?

23. Is there anything you would like to add regarding your observations on GHG emissions reduction in public transport?

THANK YOU VERY MUCH FOR YOUR ASSISTANCE

Annex 5: Questionnaire for primary data collection

This questionnaire is prepared to collect data for estimating GHG emissions from public transport **in** Kigali city. This questionnaire is expected to generate information about vehicle activity data such as kilometer traveled, fuel consumption, vehicle type and age, type of fuel used, engine type, engine capacity, vehicle age from 2012 to 2018. It is also expected to contribute to the information about which public transport mode contributes more to GHG emissions in Kigali. Your input in filling this questionnaire is therefore highly appreciated. The information provided will remain confidential, and your right to participate or not participate is respected.

Date…………………..start………end……………..time elapsed……..

A. COMPANY INFORMATION

1. Name of the company:
2. Location (district):
3. The Number of vehicles:
4. The Company opened…………

B. VEHICLE ACTIVITY DATA FROM 2012 TO 2019

5. Vehicle characteristics data:

Vehicle number plate	
Vehicle model	
Vehicle capacity (Number of seats)	
Year of manufacture	
Engine capacity	
Fuel type	
Vehicle lifetime	

6. What is the total kilometer that has been traveled by this vehicle from 2012 to 2019?

kilometer traveled per day	
Kilometer traveled per week (Monday to Friday)	
Kilometer in Weekends and holidays	
Kilometer traveled per month	
Kilometer traveled per year	
Kilometer traveled for the first six years	
Kilometer traveled for the last six years	

7. What are the records for the odometer of this vehicle for the past 6 years?

   a) What was on the odometer when the car started operating?

   b) How many years is the car in operation?
   c) What does the odometer show now?
   d) What is the average kilometer traveled by this as per the odometer per day?

8. What is the average kilometer for one trip?

9. How many trips per day/month/year

10. What is your total quantity of fuel consumption?

Fuel consumption per trip	
Fuel consumption per day	
Fuel consumption per month	
Fuel consumption per year	
Fuel consumption for the first six years	
Fuel consumption for the past six years	

C) GOVERNMENT HISTORICAL DATABASE FOR PUBLIC TRANSPORT FROM 2012 TO 2019

11. What is the total quantity for all imported petroleum products in Rwanda for the period of 2012 to 2019?

12. How much is allocated for public transport from 2012 to 2018?

13. How much is allocated for public transport (buses, motorcycles, and cars) in Kigali for the period of 2012 to 2018?

14. What is the estimated quantity of GHG emissions from public transport in Kigali from 2012 to 2018?

THANK YOU FOR YOUR TIME AND ASSISTANCE

Annex 6: Research permit issued by the Rwanda National Commission for Science and Technology

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY (NCST)
Grand Pension Plaza, 13th Floor, KN 2 Roundabout, Kigali
PO Box: 2285 Kigali – Rwanda
E-MAIL: info@ncst.gov.rw ,WEBSITE: www.ncst.gov.rw

PERMISSION TO CONDUCT RESEARCH IN RWANDA

N° NCST/482/ 188/2020

I, the undersigned, hereby grant the researcher (s) in Section I permission to conduct research in Rwanda. This permission only covers research activities related to the provided research title, during the specified period and at specified location (s) in Section II of this form.

Section I: Personal Information

1. Family Name: IRADUKUNDA Other Names: IRENE
2. Academic Qualification (Highest degree): MS, MA
3. Home Institution: UNIVERSITY OF BOTSWANA Occupation: STU

4. Phone Number (in Rwanda): 0783222220
5. Email: iradukundairene28@gmail.com
6. Primary Research Supervisor:
   a. Names: PROF. TOTENG N. ELISHA
   b. Institution: UNIVERSITY OF BOTSWANOccupation: LECTURL
   c. Phone Number: +26772732023
   d. Email: totengen@mopipi.ub.bw
7. Research Collaborators:

	Names	Institution
1		
2		
3		
4		

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Section II: Research Information

1. Research Area: ENVIRONMENT
2. Research Title: Transport and climate change mitigation policy to minimize greenhouse
3. Affiliating Rwandan Institution: UNIVERSITY OF RWANDA
4. Rwandan Supervisor:
    a. Names: MR. INNOCENT NKURIKIYIMFUI
    b. Occupation: LECTURER
    c. Phone Number: 0786976954
    d. Email: innkinno@gmail.com
5. Fieldwork Location:
    - KICUKIRO, GASABO,NYARUGENGE
    - BUS COMPANIES (ROYAL,RFTC,KBS)
    - MOTO COOPERATIVES & TAX CAR COOPERATIVES
6. Research Period:
    a. From: 5th march 2020
    b. To: 20th May 2020

Section III: Other Important Notes

- The researcher should submit the final report to NCST.

Section IV: Signature

This permission to conduct research in Rwanda is issued in accordance with Ministerial Instructions 003/2010 of 09/12/2010 regulating research activities in Rwanda.

Kigali, on 25-03-2020 NCST Ref: 188 ../NCST.2020

KALISA M. Felly

Ag. Executive Secretary

Annex 7: Recommendation letter from the University of Botswana Supervisor

UNIVERSITY OF BOTSWANA
DEPARTMENT OF ENVIRONMENTAL SCIENCE
PROF. ELISHA N. TOTENG

Private Bag UB 00704 . Gaborone. Botswana
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13th February 2020

The Executive Secretary
National Council for Science and Technology (NCST)
Republic of Rwanda
13th Floor, Grand Pension Plaza
KN 2 Avenue, Nyarugenge - Kigali - Rwanda
P.O. Box 2285 Kigali. Phone: +250781030798

REQUEST FOR SUPPORT TO CONDUCT OF A STUDY ON *"TRANSPORT AND CLIMATE CHANGE MITIGATION POLICY OPTIONS TO MINIMIZE GREENHOUSE GAS EMISSIONS AND TO PROMOTE THE USE OF PUBLIC TRANSPORT IN KIGALI, RWANDA."*

1. I refer to the above captioned matter.

2. I write in the capacity of principal research supervisor for the Master of Science research project for the bearer of this letter Mrs. Irene Iradukunda.

3. The candidate is a second-year Master of Science (MSc) Environmental Science (Climate Change and Sustainable Development) candidate at the University of Botswana, Faculty of Science, Department of Environmental Science.

4. The candidate has completed Part I of her studies, being course work. To complete her MSc study programme she is further required to undertake a research project to enable her to write her MSc dissertation on the above captioned topic.

5. We kindly request that you assist the student to the extent possible to enable her to access data and information in line with the existing laws of the Republic of Rwanda to enable her to complete her studies.

6.

I thank you in advance in anticipation of your support.

____

Prof. E.N. Toteng, PhD
Department of Environmental Science
Faculty of Science
University of Botswana
totengen@mopipi.ub.bw ; elisha.toteng@gmail.com